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OVERSIGHT

SPACE TELESCOPE: 1982

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HEARING

BEFORE THE

SUBCOMMITTEE ON
SPACE SCIENCE AND APPLICATIONS

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

NINETY-SEVENTH CONGRESS

SECOND SESSION

MAY 24, 25, 1982

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*On assignment to Budget Committee for 97th Congress.

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OVERSIGHT

SPACE TELESCOPE: 1982

MONDAY, MAY 24, 1982

House of Representatives,
Committee on Science and Technology,
Subcommittee on Space Science and Applications,
Washington, D.C.

The subcommittee met, pursuant to call, at 2 p.m., in room 2325, Rayburn House Office Building, Hon. Ronnie G. Flippo (chairman of the subcommittee) presiding.

Mr. Flippo. The committee will come to order.

Today, the Subcommittee on Space Science and Applications will begin oversight hearings on Space Telescope.

The Space Telescope is the largest development project in NASA's 1983 budget and has been a top-priority project in the Agency for some time. This seems to be entirely appropriate because it promises major advances in astronomy.

We must always remember that the prime reason for building this Telescope is scientific. Often, we get so involved in the challenge of the development that we tend to overlook the ultimate goal, which, in this case, is a better understanding of the universe through space science and astronomy.

Therefore, we want to begin this set of hearings with testimony on the Space Telescope Science Institute which will be the principal output channel through which Space Telescope results will flow. Thus, the Institute is in part a means to an end because it will facilitate good science.

But above that, it will also do good science, in-house, because it is necessary that the Institute have real scientific expertise in order to manage the Telescope most effectively.

Thus, a question that we want to look at is how the support of this in-house expertise will be balanced against outside demands for observing time.

There is a more fundamental question, however, which arises from a review of several past NASA budget requests. Such a review leads one to infer that NASA has a tendency to fight hard for funds to develop and build new missions, but does not fight equally hard for the mission operations and data analysis funds to support the missions adequately throughout their scientific life.

Let me say this may be a fault of many of us, including some in the scientific community who have been known to put capital spending on missions ahead of spending to keep missions operating and to analyze data.

The question looming before us now is whether the Space Telescope Science Institute will be adequately supported in the future. In this year's budget, NASA requested closing of the Infrared Telescope Facility in Hawaii just 2 years after its opening. Can we be assured that 2 years from now the Congress will not be fighting an administration proposal to "mothball" the Space Telescope Science Institute?

In other words, I believe the Space Telescope Science Institute is a very good idea and my concern is that it be well-executed.

Finally, let me say that I am going to solicit statements for the record of these hearings from several independent groups such as the National Academy of Sciences, and the American Astronomical Society, and similar groups.

I will ask them to give us their general views as to how the Space Telescope Science Institute should be operated, so we can conduct informed oversight of this very important institution throughout its lifetime.

With that, let me turn to our ranking minority member, Mr. Hollenbeck.

Mr. HOLLENBECK. Thank you, Mr. Chairman.

I join with you and Mr. Brown in welcoming our distinguished guests to the subcommittee today. I also share your concerns, Mr. Chairman, about NASA not adequately funding the mission operations and data analysis portions of various space projects.

As you know, the NASA request in the planetary exploration line items for research and analysis, and mission operations and data analysis would have necessitated no financial support for the Hawaiian Infrared Telescope Facility and turning off a number of Pioneer and Viking spacecraft.

I must stress the subcommittee is committed to our planetary exploration program and especially to the large number of university faculty and students employed by NASA funding in the analysis area.

We showed our support there by increasing this funding in fiscal year 1983 by $23 million.

Mr. Chairman, I, too, am concerned that we are supporting spacecraft construction without considering how to most effectively analyze returning data. The Space Telescope is a project that will literally open our eyes on the mysteries of the universe, and from there we can expect immeasurable astronomical returns.

The Space Telescope Science Institute at Johns Hopkins University will handle this the returning data. I certainly hope that in 2 or 3 years from now, we won't hear testimony from NASA about why they are not funding the Institute as we heard about the IRTF, in fiscal year 1983.

The Space Telescope Science Institute is certainly a good idea, and I hope we will fully utilize its potential.

Thank you.

Mr. FLIPPO. Thank you.

The gentleman from California , a man who has been extremely interested in the science arena for several years, and provides great leadership, a valuable member of the committee, Mr. Brown.

Mr. **Brown**. I have nothing to add, Mr. Chairman.

Mr. **Flippo**. We are very pleased to have Dr. Burton Edelson, Associate Administrator for Space Science and Applications of NASA, and I believe Dr. Franklin Martin, Director of the Astrophysics Division, Office of Space Science and Applications.

Gentlemen, we are pleased to have you and please proceed with your testimony. We will accept your full testimony for the record—feel free to summarize.

STATEMENTS OF BURTON EDELSON, ASSOCIATE ADMINISTRATOR FOR SPACE SCIENCE AND APPLICATIONS, NASA, FRANKLIN D. MARTIN, DIRECTOR, ASTROPHYSICS DIVISION, OFFICE OF SPACE SCIENCE AND APPLICATIONS, ACCOMPANIED BY FRED A. SPEER, MANAGER, SPACE TELESCOPE PROJECT, NASA, MARSHALL SPACE FLIGHT CENTER

Dr. **Edelson**. Thank you, Mr. Chairman. It is a pleasure to be here today and to be associated with an endeavor as exciting as the Space Telescope, which will be the world's most powerful astronomical instrument when it becomes operational in 1985. I would take this opportunity on behalf of the entire Space Telescope team and NASA to thank the subcommittee for its strong and continued support for this project, which is at the forefront of both science and technology.

Today, we will be reviewing the status of the Space Telescope Science Institute and selected ground segments. Tomorrow, we will be presenting the status of the spacecraft and telescope systems.

Dr. Frank Martin, Director of the Astrophysics Division in the Office of Space Science and Applications, will provide the subcommittee with a brief overview and status of the relevant elements for each set of hearings. I should mention that Dr. Fred Speer, who is the project manager for the Space Telescope at Marshall Space Flight Center, is also with us today.

As a result of my initial exposure to the Space Telescope project, I was impressed by the technical complexity and management challenges. After becoming familiar with the various elements of the project, there is one thing that impresses me even more, and that is the quality and dedication of the people working on it. They have overcome many difficulties to get where we are now. I am confident that they will overcome any difficulties ahead, resulting in an achievement of the first magnitude.

Now, Mr. Chairman, I would like to call on Dr. Martin to continue with an overall description of the program.

Mr. **Flippo**. Very good.

Dr. **Martin**. It is a pleasure to be here this afternoon and to have Dr. Speer with us. You may remember that he participated in several field hearings before your subcommittee. Bearing in mind that one of these field hearings just occurred this past February, we will try to limit our comments and overview.

If I could have the lights down briefly, I would like to show you a picture of the Space Telescope (fig. 1). In observing pictures in this room of the other NASA achievements that the subcommittee has supported, I would like to suggest to the chairman that if we could find a place on the walls, we would like to provide you with a proper picture of the Telescope, possibly looking in another direction.

Mr. FLIPPO. We would be pleased to receive that.

Dr. MARTIN. We will be here for 2 days. The first day is dedicated to the Space Telescope Science Institute, the operation of the Telescope, and the science aspect of it. Tomorrow, we will discuss the hardware segment.

The concept of the Institute (fig. 2) goes back to at least 1966, as far as I can tell from our records. It was recommended by a number of rather distinguished science groups that NASA should own the Telescope and involve the science community in the operations of that Telescope in much the same way that ground-based observatories have been operating. Probably the most notable recommendation is the last one, emphasized by Professor Horing in the National Academy of Science study which recommended to NASA in 1976 the mode of implementation for such an Institute.

NASA subsequently conducted its own study of the Horing committee recommendations. After looking at the possibility of operating the Telescope in-house through the Goddard Space Flight Center or through an institutional mode, NASA decided on a concept that resulted in the release of a request for proposal in December of 1979.

Subsequent to that and the evaluations of five proposals, the Associated Universities for Research and Astronomy [AURA] was selected as a consortium to head up the Space Telescope Science Institute and a site, which AURA proposed, was also picked at the Johns Hopkins University in Baltimore, Md.

We have with us today the Director of that Institute, Dr. Riccardo Giacconi, who was appointed after the award of the contract.

Figure 3 will give you some idea of where the Institute stands in terms of the responsibilities of the Space Telescope project. You can see a lot of hardware there. At the top of the figure is Marshall Space Flight Center which is responsible for project management. Lockheed handles the spacecraft segment and the systems engineering. Perkin-Elmer is responsible for the optical systems. The European Space Agency is providing the solar hardware and the personnel to the Institute, as indicated on the chart.

The Goddard Space Flight Center has overall responsibility for mission operations and for the remainder of the science instruments. We will have two cameras, two spectrometers, and a photometer on board the spacecraft, and we are planning on doing astrometry, the precision location of stars and objects using the guidance system on board.

The Institute has a contract through Goddard as indicated on the figure. The Johnson and Kennedy Space Centers are responsible for the Shuttle systems. The Shuttle allows us the ability to maintain the Space Telescope for about 10 to 12 years and that is really what makes this a unique telescope.

In terms of how the Space Telescope Science Institute fits in with the rest of the operation (fig. 4), the spacecraft itself is operated out of Goddard Space Flight Center. The people who are actually directing the spacecraft are NASA employees. The Institute is located in Baltimore, but it has a planning arm located at Goddard where the actual real-time planning and interfaces with the spacecraft operators occurs.

This Institute—figure 5—is a little bit different than the kind of institutes that are involved with ground-based telescopes. In many cases, the ground-based telescopes are built and operated by the institute, whereas, the Space Telescope Science Institute is primarily one of science operations. NASA already has institutional capabilities to build spacecraft and to handle spacecraft operations. NASA decided, after much review and discussion, to turn the science operations over to an independent institute. Depicted on the right-hand chart is the interface with the science community.

Typically, once the telescope is up and operating, the scientists will submit a proposal to the Institute in response to solicitations for observations. The Institute will do the planning, managing, and scheduling of these observations and prepare a plan that will then be fed into the Payload Control Center at Goddard Space Flight Center. Any real-time adjustment to that plan will be handled by the Science Support Center, which is an arm of the Institute located at Goddard.

Payload Control Center will send commands to the spacecraft via a domestic communications satellite and our tracking and data relay satellite system.

The observations will be made, and the science data will be returned, along the same link, to the NASA data capture facility. From there, the data will be sent out to the Institute for distribution to the science community.

Mr. **Flippo**. May I interrupt you for just 1 minute. This might be the proper place to ask this question: How dependent on the TDRSS is this telescope?

Dr. **Martin**. My understanding is that TDRSS is scheduled for launch later this year, and the total TDRSS system should be up and operating long before the launch of the Space Telescope. If for some reason, that system is not in place, it will certainly hamper our ability to operate, but we do have the backup capability to use ground stations to collect the data and we would do that if we had to.

Mr. **Flippo**. Thank you.

Dr. **Martin**. Are there any further questions in terms of the basic operations described here?

Now, the Institute also has other responsibilities. It puts the data in a format that is useful to the user community. It also has the responsibility to conduct basic research. We do want a quality Institute with practicing scientists there to interface with the rest of the science community. We do not plan to put their data in the National Space Science Data Center. That will be handled at the Space Telescope Science Institute. The science community has an element of responsibility for informing the public. This briefly describes in general terms the operation of the Institute.

The current contract with AURA is approximately $40 million through 1986. Funding through fiscal year 1982 was about $5.5 million. Approximately $7 million will be provided to the Institute in 1983.

Mr. Flippo. Would you elaborate briefly on the user community—that is, who can make a request of the Institute for observations?

Dr. Martin. I think anyone can respond to an announcement from the Institute on the availability of observing time. Next, there is a peer-review process to screen respondents because the observing time on Space Telescope is indeed very valuable. Thus, a person would have to demonstrate scientific credentials to obtain a science observation opportunity.

As far as the general public is concerned, if an individual were not scientifically competent enough to win observation time, he certainly has access to the information through the Public Information Office of the Institute.

That concludes my comments, unless there are other questions.

[The prepared statement of Dr. Martin follows:]

Statement of Dr. Franklin D. Martin

Mr. Chairman and Members of the Subcommittee: As an introduction to testimony on the Space Telescope Science Institute, I believe it is appropriate to review the underlying philosophies for the establishment of the Space Telescope Science Institute and its relationship to the science users of the Space Telescope.

The Space Telescope will become the world's most powerful astronomical telescope when it becomes operational in 1985. Celestial objects fifty times fainter and seven times more distant than detectable from ground-based optical telescopes will be studied, and the observable volume of the universe will increase by a factor of 350. By providing for on-orbit servicing, repair, and refurbishment of on-board instrumentation, this 94-inch telescope will be the heart of the United States space astronomy program until the end of the century. Chart No. 1 is an artist's concept of how the Space Telescope will appear in orbit.

As you are aware, there are a large number of people and organizations involved in developing the Space Telescope and preparing for mission operations. Overall management of the Space Telescope Project is the responsibility of NASA's Marshall Space Flight Center. Chart No. 2 shows the groups responsible for the major elements under the direction of the Space Telescope Project Office. You will note that the Goddard Space Flight Center is responsible for operation of the Space Telescope spacecraft, as well as the Space Telescope Science Institute. The European Space Agency is contributing the Solar Arrays, the Faint Object Camera, and some operational support to the Space Telescope Science Institute.

A major goal in our planning process for Space Telescope operations has been to insure a significant role for the scientific community in the generation and implementation of the science observation program. Because of the planned long life of the Space Telescope, we recognized that our past procedures for conducting science observations from spacecraft were not necessarily applicable. After about a year in orbit, the telescope will be used the majority of time by "general observers." These users will be selected under the auspices of the Space Telescope Science Institute on the basis of proposals solicited periodically.

Over the years, a number of astronomical groups studied the question of whether or not a Space Telescope Science Institute should be established (Chart No. 3), rendering the science operations for the Telescope similar to that for large, ground-based facilities. The last such group was the 1976 National Academy of Sciences study group, chaired by Professor Donald F. Hornig, which strongly recommended the establishment of a Space Telescope Science Institute and outlined, in some detail, the functions, structures, and implementation mode for the recommended Institute. A NASA study group subsequently made detailed studies of scientific management options ranging from a totally-internal, NASA-managed operation to an independent institute. At that time, it was recognized that service to the scientific community must be the number-one priority of the selected institute concept.

After studying the question at considerable length, we concluded that the most scientifically-efficient and satisfactory approach to science operations was to establish an independent Space Telescope Science Institute which would be operated under a long-term contract with NASA. The Space Telescope Science Institute will solicit and select observing proposals, plan and schedule an integrated science program, control the utilization of the on-board scientific instruments, and support the post-observational processing and archiving of science data. The key operational functions of the Institute are listed in Chart No. 4.

The overall concept which has been established for the conduct of Space Telescope operations is represented in Chart No. 5. NASA is responsible for overall management of the program, including definition of general policy and provision of funding. In addition, NASA will remain responsible for the overall science policy, the health and safety of the Space Telescope spacecraft, and the potential development of new or modified scientific instruments for later installation on the spacecraft.

The magnitude of the Science Operations Ground System (SOGS) development is such that it requires an experienced ground system contractor and an experienced technical management organization to manage that contract. Therefore, the independent institute concept adopted by NASA included the provision that the SOGS would be developed by NASA. We currently plan to slowly build up the Space Telescope Science Institute manpower to full strength prior to launch of the Telescope in 1985. The SOGS contract was awarded to TRW, Inc., in December 1981; and the SOGS hardware and software is scheduled to be delivered to the Institute in advance of the launch of the Telescope.

The Request For Proposals for the Space Telescope Science Institute was released in December 1979. Five proposals were received and evaluated. The two major program objectives of the procurement were to maximize the scientific usefulness and effectiveness of the Space Telescope, and to bring the user community into direct contact with the control of the science. On the basis of the evaluations of the proposals, the Association of Universities for Research in Astronomy (AURA) was awarded a contract in April 1981 to establish, operate, and maintain the Space Telescope Science Institute. The Institute is being established on the Homewood Campus of the Johns Hopkins University, in Baltimore, Maryland.

The Institute has begun staffing and has selected a Director, Deputy Director, Program Manager, and personnel for other key positions. Because they are newly formed, it has been necessary for them to develop management and operational plans and other standards necessary for an organization to perform. They are in the process of developing a guide star selection system and a science data analysis system for integration into the SOGS. More detailed status of both the Space Telescope Science Institute and SOGS contracts will be presented by representatives of these efforts.

The funding requested for Space Telescope Operations in fiscal year 1983 is $32.8 million. Of this amount, approximately $7 million will go to the Space Telescope Science Institute. The remainder is required for the SOGS contract and other preparatory efforts for mission operations.

Mr. Chairman and members of the Subcommittee, that concludes my testimony. I would be pleased to answer any questions from the Subcommittee.

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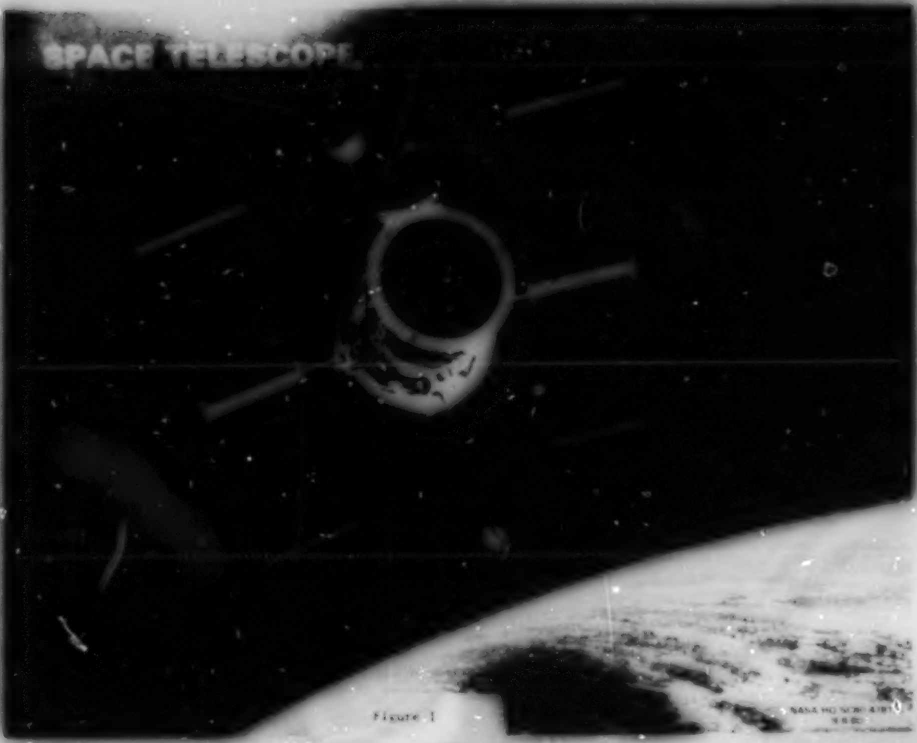


Figure 1

NASA HQ [illegible]

RECOMMENDATIONS ON THE METHOD OF SPACE TELESCOPE SCIENCE OPERATIONS

(ALL IN FAVOR OF THE SCIENCE INSTITUTE APPROACH)

DATE	ORGANIZATION
1966	REPORT OF STUDY HEADED BY NORMAN RAMSEY
APRIL 1975	ST SCIENCE WORKING GROUP · BODY OF SENIOR SCIENTISTS SELECTED BY ANNOUNCEMENT OF OPPORTUNITY TO PARTICIPATE IN THE PRELIMINARY DESIGN PHASE OF ST
AUGUST 1975	COUNCIL OF THE AMERICAN ASTRONOMICAL SOCIETY · ELECTED COUNCIL OF THE ONLY PROFESSIONAL ASTRONOMICAL SOCIETY IN THE UNITED STATES
NOVEMBER 1975	LST STUDY GROUP · AD HOC BODY OF SCIENTISTS CONVENED BY THE ASSOCIATE ADMINISTRATOR TO PROVIDE AN OVERVIEW OF THE ST PROGRAM
FEBRUARY 1976	SHUTTLE ASTRONOMY MANAGEMENT AND OPERATIONS WORKING GROUP – SCIENTIFIC WORKING GROUP CHAIRED BY THE CHIEF OF THE ASTRONOMY AND RELATIVITY OFFICE OF THE OFFICE OF SPACE SCIENCE
DECEMBER 1976	NATIONAL ACADEMY OF SCIENCES – REPORT OF THE SPECIAL STUDY HEADED BY PROFESSOR HORNIG

Figure 2

NASA HQ SC78-[illegible] (1)
7-3-78

SPACE TELESCOPE PROJECT RESPONSIBILITIES

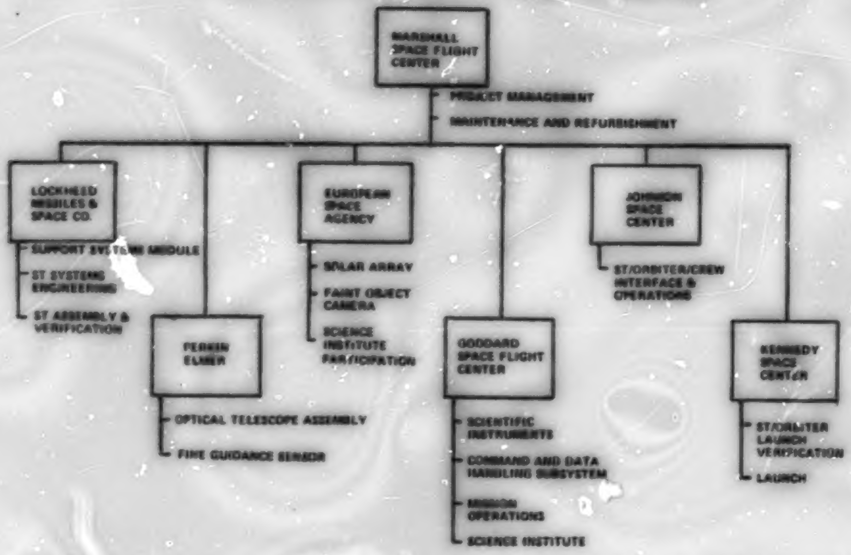
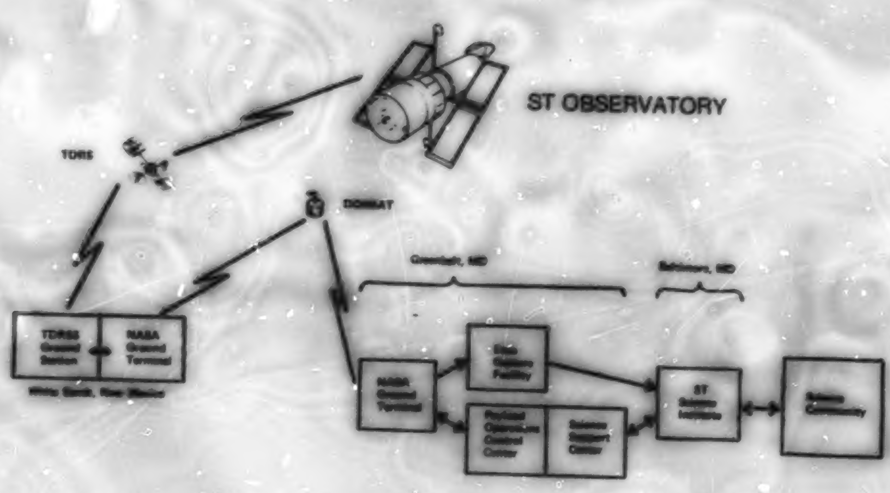

MARSHALL SPACE FLIGHT CENTER
PROJECT MANAGEMENT
MAINTENANCE AND REFURBISHMENT
LOCKHEED MISSILES & SPACE CO.
SUPPORT SYSTEMS MODULE
ST SYSTEMS ENGINEERING
ST ASSEMBLY & VERIFICATION
PERKIN ELMER
OPTICAL TELESCOPE ASSEMBLY
FINE GUIDANCE SENSOR
EUROPEAN SPACE AGENCY
SOLAR ARRAY
FAINT OBJECT CAMERA
SCIENCE INSTITUTE PARTICIPATION
GODDARD SPACE FLIGHT CENTER
SCIENTIFIC INSTRUMENTS
COMMAND AND DATA HANDLING SUBSYSTEM
MISSION OPERATIONS
SCIENCE INSTITUTE
JOHNSON SPACE CENTER
ST/ORBITER/CREW INTERFACE & OPERATIONS
KENNEDY SPACE CENTER
ST/ORBITER LAUNCH VERIFICATION
LAUNCH

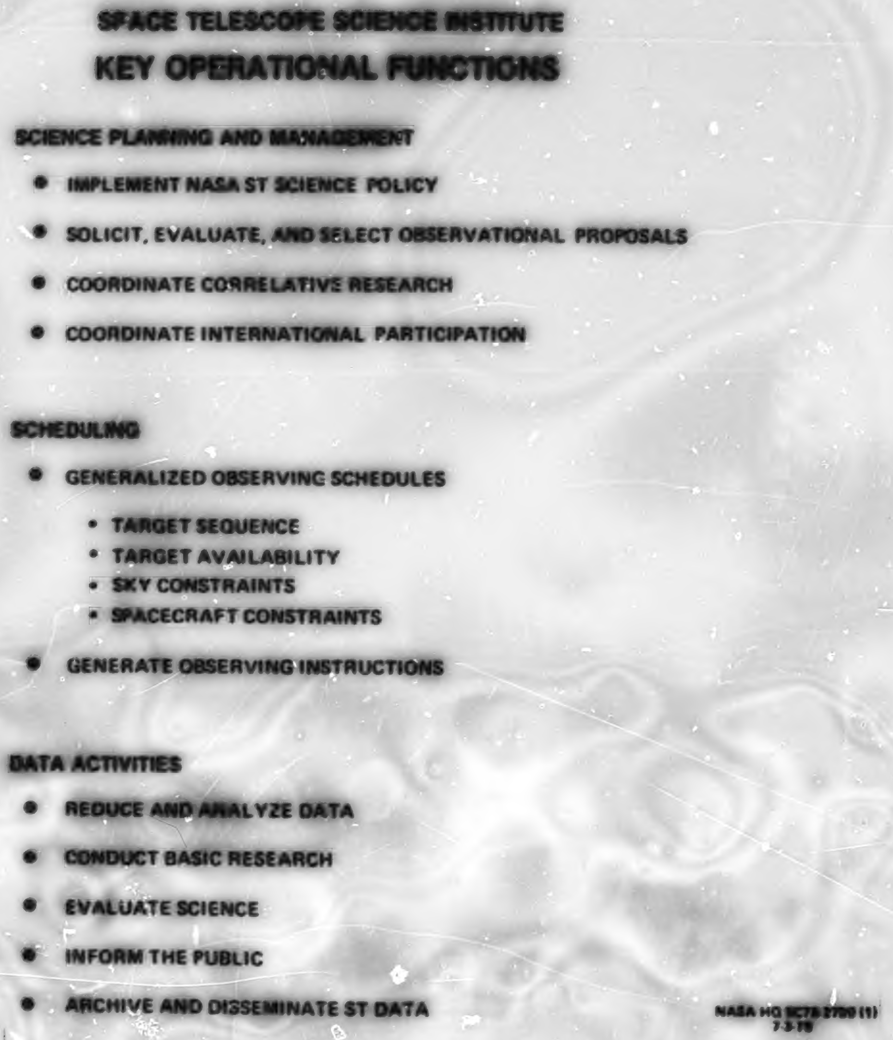
Figure 3

NASA HQ E232-1013 (1)
5-14-82


ST OBSERVATORY
TDRS
DOMSAT
Greenbelt, MD
Baltimore, MD
TDRSS Ground Station
NASA Ground Terminal
White Sands, New Mexico
NASA Ground Terminal
Data Capture Facility
Payload Operations Control Center
Science Support Center
ST Science Institute
Science Community

ST OPERATIONAL ELEMENTS

NASA HQ E232-1012 (1)
5-14-82



SPACE TELESCOPE SCIENCE INSTITUTE
KEY OPERATIONAL FUNCTIONS

SCIENCE PLANNING AND MANAGEMENT

- IMPLEMENT NASA ST SCIENCE POLICY
- SOLICIT, EVALUATE, AND SELECT OBSERVATIONAL PROPOSALS
- COORDINATE CORRELATIVE RESEARCH
- COORDINATE INTERNATIONAL PARTICIPATION

SCHEDULING

- GENERALIZED OBSERVING SCHEDULES
  - TARGET SEQUENCE
  - TARGET AVAILABILITY
  - SKY CONSTRAINTS
  - SPACECRAFT CONSTRAINTS
- GENERATE OBSERVING INSTRUCTIONS

DATA ACTIVITIES

- REDUCE AND ANALYZE DATA
- CONDUCT BASIC RESEARCH
- EVALUATE SCIENCE
- INFORM THE PUBLIC
- ARCHIVE AND DISSEMINATE ST DATA

NASA HQ SC78-2700 (1)
7-3-78

Figure 5

Mr. **Flippo**. Mr. Hollenbeck?

Mr. **Hollenbeck**. I have no questions.

Mr. **Flippo**. Mr. Brown.

Mr. **Brown**. You didn't mention what the orbital situation was, did you?

Dr. **Martin**. The launch of the Space Telescope?

Mr. **Brown**. Yes.

Dr. **Martin**. Our plan is to launch it on direct ascent with the Space Shuttle at 320 nautical miles.

Mr. **Brown**. Describe to me what an orbit will be like in terms of the astronomical fields that it will be able to cover.

Dr. **Martin**. The telescope itself looks out from the Earth. We are certainly dependent on the location of the Moon, the Sun and the Earth; but over the period of a year, the entire universe, as far as the telescope can see, should be available to us.

Mr. **Brown**. Everything?

Dr. **Martin**. Everything.

Mr. **Brown**. You can change the direction?

Dr. **Martin**. That is correct. The orbital inclination is 28 degrees, so that makes both the Northern and Southern Hemisphere available to you.

Mr. **Brown**. How many institutions are involved with the Institute? I presume these are universities with strong astronomy departments?

Dr. **Martin**. I would like to defer to Dr. Spitzer, if I could.

Dr. **Spitzer**. AURA is a consortium made up of 17 universities.

Mr. **Brown**. Are those all of the universities with their graduate departments of astronomy or a major part of them?

Dr. **Spitzer**. Not necessarily. It includes the bulk of the ones with strong departments. On the other hand, it should be pointed out the fact that because a university is a member of AURA, that does not give that university any special right as members of—they have representatives that sit on the AURA Board and help determine policies.

Mr. **Brown**. They have the responsibility for serving as part of the governing board but no special privileges in terms of observing.

Dr. **Spitzer**. That is correct.

Mr. **Brown**. What is the incentive to get them to accept the responsibility without any extra privileges?

Dr. **Spitzer**. Speaking as a representative of Princeton University, to get people to serve on the AURA Board, we urge the importance of this for their own work of having a successful and effective organization, in this case for ground-based observations.

Some very good people are serving on the AURA Board.

Mr. **Brown**. They have not been geographically confined to any one area?

Dr. **Spitzer**. No. We represent all parts of the United States.

Mr. **Brown**. I was very much interested in this form of management for scientific enterprises and I would appreciate it if someone would comment briefly as to how this compares with some of the other similar kinds of scientific management structures.

I am thinking here of the Associated Laboratories for Energy Research or the National Center for Atmospheric Research. Is there a conscious similarity in these or are they each ad hoc expressions of the proper way to meet an immediate need?

Dr. MARTIN. I think in this case what you are seeing is an institute which isn't directly responsible for the building of the hardware. but is responsible for the operation of the facility. In many of the consortia, as mentioned, were put together to build the facility and the scientific hardware as well as to operate them.

What we do have with the Institute, I believe, is a very good relationship where the scientific integrity of the telescope is closely watched and coordinated with all parties. So in that sense, it is a very different kind of an institute than the ones you talked about.

Mr. BROWN. I have no further questions, Mr. Chairman.

Mr. FLIPPO. Thank you.

I would like to know how you determine the flight priorities. Can an STSI user be bumped for military use of TDRSS?

Dr. MARTIN. Whether the military would want to make an observation with the Space Telescope?

Mr. FLIPPO. I am really trying to understand how TDRSS and STSI successfully interact. Does the military have priority on TDRSS?

Dr. MARTIN. Whether or not they could preempt?

Mr. FLIPPO. Yes.

Dr. MARTIN. I don't know what the priorities are. I think there are others in the Agency who could better testify to that. However, I would like to point out that there are tape recorders on board the Space Telescope. We are not continuously dumping data, so there are ways for us to work around other users and other priorities on the TDRS system.

Mr. FLIPPO. Since NASA has traditionally been weak in supporting mission operations and data analysis, can you give us any assurances that this Institute will be adequately supported over its lifetime?

By that, I am interested as to whether or not this uncertain funding support makes it difficult to attract high-quality scientific staff or is that a problem?

Dr. EDELSON. I will try to answer that, Mr. Chairman.

As of now, the Space Telescope program, including the Space Telescope Science Institute, is fully funded. This is a program which NASA recognizes is of great importance. In my own area the Space Telescope is the centerpiece of our entire space science program. We are committed to doing a good job on all elements of the program, including getting the hardware into orbit, keeping it working properly, getting all the data back and certainly, as you point out, the analysis of the data and the research—supporting the research that the data will provide.

It is our intention to keep this fully funded, Mr. Chairman. We are glad to do so, because we think it will pay off very handsomely in terms of the scientific dividend this instrument will have.

Mr. FLIPPO. Is this an annual contract with the Agency and with the Institute?

Dr. EDELSON. The contract isn't annual. It is funded on an annual basis.

The contract with the AURA is renewable every 5 years. NASA has an option to say yes or no. If we say yes, AURA has to renew it for 20 years.

Mr. **Flippo**. Is the contract basically for operations or does it also include an element for facilities?

Dr. **Martin**. What do you mean by facilities—buildings?

Mr. **Flippo**. What pays for the construction of the Institute facilities?

Dr. **Martin**. I will defer to Dr. Riccardo Giacconi, Director of the Space Telescope Science Institute. We are presently living in temporary quarters furnished by Johns Hopkins. We pay them rent. They will continue to act as our landlord. They are constructing a building now on the basis of bonds and aid from the State of Maryland Legislature and then they will rent this building to us. The contract includes funds for paying the lease.

Mr. **Flippo**. So the contract, the contract between NASA and the Institute, will cover the capital cost of the Institute. Is that sufficient to amortize the cost of the equipment over the lifetime of the bonds?

Dr. **Giacconi**. Yes, except for the designation from the Maryland State Legislature of the $2 million which would not be recovered.

Mr. **Flippo**. Are there any in-kind services associated with that contribution by the great State of Maryland?

Dr. **Giacconi**. No.

Mr. **Flippo**. Concerning the pricing policy for services, will the Institute charge for these observations?

Dr. **Giacconi**. Actually, the Institute pays the investigators who analyze the data and conduct the research when he comes there.

The only items I know of there would be a charge for would be only public information-type material, which would put some necessary burden on the Institute, but there are no user charges, per se, at the Institute.

Mr. **Flippo**. I am very interested in the peer group review of how the user comes in. I know very little about it, but it seems to me many years ago, Aristotle developed a concept of the universe and then along came a fellow named Galileo who had a different concept.

Some said Galileo couldn't be right because Aristotle couldn't be wrong.

The peer group review probably wouldn't have let Galileo have an observation on the telescope. Is that essentially right? How does that peer group work?

Dr. **Martin**. I think there is a difference in the case of the Space Telescope. The Space Telescope will be so revolutionary that it really doesn't matter which one of the gentlemen gets to see what is coming down. It is going to change our views of the universe.

Mr. **Flippo**. Thank you very much for your testimony.

Mr. **Brown**. Could I ask a question?

Mr. **Flippo**. Certainly.

Mr. **Brown**. With regard to your linkages with the international astronomy or scientific community, is this going to be on the same basis, as I understand it, as the ground-based observatory situation? That is, foreign observers will be welcomed on the same basis.

Dr. **Martin**. We plan to provide 15 percent of the observing time on the Space Telescope to investigators from ESA member nations.

Mr. **Brown**. What is that estimate based on?

Dr. **Martin**. That is based on an earlier estimate as to the amount that ESA's contribution would be over the lifetime of the Commission.

Mr. **Brown**. Is this in any formal memo?

Dr. **Martin**. We have a formal memorandum of understanding with ESA.

Mr. **Brown**. What about the rest of the world?

Dr. **Martin**. Anyone from the rest of the world can propose. If they are not from an ESA member state, they can propose time on the telescope and compete with others. There is no formal agreement with any other element.

Mr. **Brown**. The statement on the peer review reminded me of the problem in the community right now with regard to observing time on one of the telescopes, one of the ground-based telescopes. I am trying to recall the details, but some astronomer with a kooky theory is running out of observing time because nobody seems to agree with his theory any longer.

Dr. **Martin**. I can't really comment on that. I can tell from our Space Telescopes that observer time is oversubscribed at all the facilities around the country and around the world. There is a lot of controversy about who gets time on telescopes.

Mr. **Brown**. There have been a couple of articles on this in various science magazines. It illustrates that the matter is not yet fully resolved as to how well peer review works.

Mr. **Flippo**. The distinguished gentleman from New Mexico, Mr. Lujan.

Mr. **Lujan**. You were talking about planetary exploration outside of the solar system. Will you do some observations within our solar system?

Dr. **Martin**. Yes. In fact, the Space Telescope will provide some very powerful observations of planets and planetary atmospheres in particular.

Mr. **Lujan**. Will this Telescope give us better data than Pioneer or Voyager?

Dr. **Martin**. We will get better pictures of Jupiter, for example, with the Space Telescope in Earth orbit than we do with Pioneer. On a regular basis, observations of Jupiter will be competitive with many of the close-by pictures that were taken with Voyager but not the very high-resolution ones. It will be a very powerful tool for planetary astronomy and a major element of the Space Telescope program.

Mr. **Lujan**. What interplay is there between the Space Telescope and the very large array of listening devices? This is optical. Is there a combination of data?

Dr. **Martin**. We are finding that in astronomy, particularly in the last 10 to 20 years, that the astronomers are beginning to look at all wavelengths of the universe. Dr. Giacconi's experience with the HEAO program, the high energy astronomical observatories, opened up the X-ray universe for us. The radio-telescopes in New Mexico are a part of that, and when you look in these different regions of the spectrum, you see different physics, different processes and it is all part of putting the puzzle together to understand the universe.

Mr. **Lujan**. You combine the data from each one in order to better understand, so there will be some interplay.

Dr. **Martin**. That is correct. There is synergy that occurs in that element as shown the chart that I displaced earlier, which you may not have seen, called "The Science Community."

Mr. **Lujan**. Thank you, Mr. Chairman.

Mr. **Flippo**. Gentlemen, thank you very much for your testimony. We appreciate having you here. We will now take our next panel of witnesses, Drs. Spitzer and Giacconi.

Gentlemen, we are delighted to have you with us today, and we look forward to your testimony.

You may proceed as you deem appropriate.

STATEMENT OF DR. LYMAN SPITZER, PRINCETON UNIVERSITY OBSERVATORY

Dr. **Spitzer**. I speak to you today with a tremendous enthusiasm for the Space Telescope, based on some 35 years of my own personal commitment to this program. A more official reason for this talk is my position as chairman of the Space Telescope [ST] Institute Council, which AURA—the Association of Universities for Research in Astronomy—has set up for the management oversight of the ST Science Institute. My talk will outline the activities of AURA in general and of the ST Institute Council in particular relating to the ST Science Institute, and will describe some of the problems we have faced and those we anticipate.

Mr. **Brown**. Pardon me for interrupting. Did you say 35 years?

Dr. **Spitzer**. Yes.

Mr. **Brown**. Do you want to explain that?

Mr. **Flippo**. I think it is a very interesting point, Mr. Brown.

Dr. **Spitzer**. I became interested in this about 1946, when rockets first became a realistic possibility for science.

Mr. **Brown**. Long before we had a space program?

Dr. **Spitzer**. Yes, sir.

Mr. **Brown**. That was my point.

Mr. **Flippo**. A man with such vision. What do you see as the follow-on to the Telescope?

Dr. **Spitzer**. There are many possibilities. I would hesitate to commit myself in this gathering. I am sure what the Space Telescope tells us will help guide what we wish to do next.

First a brief word about AURA, which has contracted with NASA for managing the ST Science Institute. This organization, a consortium of 17 U.S. universities, was created in 1957 to provide national telescope facilities for visiting astronomers from all over the country. It now operates and manages three centers for optical observations as well as the ST Science Institute.

The primary tasks of AURA in connection with these centers are: to establish policies governing the operation of AURA which are consistent with contractual requirements and in the best interests of science; to exercise management oversight of its centers so as to facilitate the conduct of their missions and supporting tasks; to interact with funding agencies to ensure mutual understanding of the relevant problems; to establish an AURA-wide operational environment in which both AURA staff and external users of these centers can function most effectively; and to provide for internal and external evaluation of the performance of the centers and of AURA.

Organizationally, AURA is run by a president, Dr. John Teem, who reports to the AURA Board of Directors. The director of the ST Science Institute, Dr. Giacconi, reports through President Teem to the board. The ST Institute Council functions as a subcommittee of the board for all matters relating to the ST ScI; of the 12 members of this council, 8—including President Teem—are board members. On some administrative matters, especially personnel actions, the ST Science Institute follows AURA policies very closely. On others, especially those concerned with scientific and technical matters, the necessary policies are developed in joint consultation between the ST Institute Council, and the direction of the ST Science Institute, often with active participation by NASA officials as well.

I should point out that relations with NASA lead to a very important administrative difference between the management structure for the ST Science Institute and the more normal structure for a division of a corporation of a university. Much of the work by the Institute, especially before the ST is launched, is followed in great detail by NASA, especially by staff members at the Goddard Space Flight Center. It would be an unnecessary duplication of effort and a costly burden on the ST Science Institute if AURA, through its ST Institute Council, were to follow the technical work at the ST Science Institute in the same detail. Instead, our policy has been to maintain only a general oversight of ST Science Institute activities, and rely largely on close relations with NASA for their evaluation of how the work is proceeding.

Let me pass now to a brief summary of AURA activities to date with respect to the ST Science Institute. As you can well imagine, getting the Science Institute started in early 1981, with an acting director—Dr. Arthur Code—and a skeleton staff, was a demanding task, in which Dr. John Teem and his staff played a very crucial role. Particular areas in which the AURA Corporate Office had major responsibilities were: negotiation of the prime contract with NASA for the ST ScI; early negotiations with Johns Hopkins University with respect to temporary and permanent office space; negotiations of a suitable contract with the CSC Corp., whose staff will carry out many of the operational functions of the ST Science Institute; supervision of the procedures for hiring new personnel and of an appropriate salary scale.

The most important activity of the ST Institute Council to date has been its search for a permanent director and deputy director. Many applicants for these two positions were evaluated, as were a large number of astronomers who had not applied but who were regarded as potentially suitable. I believe that we are most fortunate that AURA was able to persuade Dr. Riccardo Giacconi, an extraordinarily capable and internationally famous scientist and organizer, to serve as director. His deputy, Donald Hall, also combines research statutre with important experience in high-level scientific administration.

At the moment, the ST Institute Council is carrying out a similar search for six members of a Visiting Committee, which will survey as least once each year the general program of the ST Science Institute, and advise the council—and, through proper channels, the AURA Board and NASA—of any changes in policies or procedures that seem desirable. Such visiting committees are familiar in academic and scientific organizations, and should provide one of the many mechanisms for keeping the Science Institute in touch with the astronomical community. A ST Users' Committee, which reports to the director, ST Science Institute, will provide another such mechanism. These committees will give particular attention to the detailed interactions between research astronomers and the Space Telescope, a topic which becomes of overwhelming importance after the launch, and which NASA will presumably not follow in the same detail as it does the prograss of the ST Science Institute toward operational readiness at the time of launch.

Other activities of the ST Institute Council have mostly been in the policy area. We have considered problems brought to our attention by Director Giacconi, by President Teem, or by NASA. Our role is essentially advisory, but appears to have been useful. To provide examples of our policy activities, I shall describe here two of the issues we have considered.

The first is the so-called problem of "data rights"—how long should be the "proprietary period" in which data obtained with ST by a visiting astronomer are reserved for use by that astronomer. At the end of the proprietary period, the data will be made generally available to any one requesting the information. We discussed in some detail how long a time should normally be required to analyze data and publish at least a summary of the results. Also relevant is the likelihood that too short a proprietary period might encourage astronomers to carry out rather superficial, hasty analyses, and thus be a detriment to the quality of science carried out by ST. A policy statement in this area was first drafted by NASA, and after full discussion of all parties, involved was modified to include a somewhat flexible policy, with a normal 1 year proprietary period, with extension to 2 years possible by the director "if dictated by compelling scientific requiremens," and with extensions beyond 2 years possible only in the most compelling cases.

A second issue we considered was whether, and under what circumstances, a complete copy of the ST data archives should be sent to a foreign nation, including the European Space Agency, which has made tentative plans to set up such a duplicate set of ST archives at a European center in Munich. After extensive discussions, the ST Institute Council endorsed the proposed transmission of archival data to the European Space Agency (all costs to be paid by Europeans), but recommended that additional flexibility as regards specific arrangements be provided in any agreement. We understand that such a policy is being followed by NASA.

What policy problems do we anticipate in the future? One matter which will be discussed at our next meeting will be the question of protecting the specific observing programs planned by the astronomers who have developed the ST instruments; that is, other astronomers will not be allowed to observe objects in ths sky that are protected. The instrument astronomers are guaranteed a certain amount of observing time on ST during the first 2½ years of orbital operation. Decisions must be reached on exactly how such protection is to be provided, how long it lasts, what changes will be allowed, and similar problems. It is important to set up regulations that are regarded as equitable both by astronomers who have devoted years of effort to instrument development, and are given protected time, and by the astronomical community of ST users generally. This is a topic on which NASA is taking the initiative, because of its formal responsibilities to the astronomers on instrument development teams; again detailed discussions between all interested groups should help to reach a satisfactory consensus.

Another problem area is how to react if, as expected, requests for observing time on ST greatly exceed 24 hours per day. Should most proposed programs be reduced in scope, so that a large fraction can be approved, or should a few of the very best, most important proposals receive all the time they need? The enormous power of the ST makes this instrument so attractive that allocation of time poses severe problems; to optimize scientific effectiveness without sacrificing equity is clearly a desirable, but probably difficult, goal.

In closing let me emphasize the general enthusiasm which the astronomical community continues to demonstrate for ST, an enthusiasm which has generated valuable support for this enterprise in many different ways. Let me emphasize also the firm dedication to this fundamentally important program on the part of the AURA staff, both in Tucson and in Baltimore, and on the part of the many NASA personnel actively involved. I am confident that the ST Science Institute will operate with the greatest possible effectiveness for the advancement of astronomy, and that ST will be one of the most important scientific tools of this century.

[The prepared statment of Dr. Spitzer follows:]

BEST DOCUMENT AVAILABLE

May 24, 1982

Statement to Subcommittee on
Space Science and Applications,
Committee on Science and Technology,
U. S. House of Representatives

by

Lyman Spitzer, Jr.
Charles A. Young Professor of Astronomy
Princeton University

Summary biography of L. Spitzer

Born in Toledo, Ohio, June 26, 1914.

Educated at Yale (B.A., 1935) and Princeton (Ph.D., 1938) Universities.

Yale faculty member, 1939-1947; on leave 1942-46 for World War II undersea warfare research.

Professor of Astronomy, Princeton Univ., 1947-1983; Director, Princeton University Observatory and Chairman of Astronomy Department, 1947-1979.

Started controlled fusion research in plasma physics at Princeton University in 1951, and remained in charge of this work as head of the Plasma Physics Laboratory until 1966.

Principal Investigator for Orbiting Astronomical Observatory No. 3 (Copernicus), which observed ultraviolet stellar spectra from 1972 to 1981.

Author of several technical books on plasma physics and interstellar matter; numerous articles on these topics and on stellar dynamics and space astronomy.

National Medal of Science 1980. Member National Academy of Sciences since 1952.

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LS:vm
5/24/82

Mr. Flippo. Thank you, Dr. Spitzer. We will now be delighted to hear from Dr. Giacconi.

STATEMENT OF DR. RICCARDO GIACCONI, DIRECTOR, SPACE TELESCOPE SCIENCE INSTITUTE

Dr. Giacconi. Mr. Chairman and members of the committee, I am very grateful for this opportunity to discuss with you Space Telescope. I think that this offers an important channel for dialog which may become important in the future.

I was particularly grateful for the sentiments of sympathy and support to STSI and to the activities that the Space Telescope Science Institute will conduct which you expressed.

I think I will not repeat the statements about the importance of the Space Telescope which have been made by many of the previous witnesses. I obviously believe in that. Otherwise I wouldn't have taken on this responsibility.

I believe it will be one of the most exciting scientific enterprises in the next 10 years. I think it is a very precious capability and facility, unique in the world and one of the most important tools for scientific research available to man in the next decade.

I think it is particularly important that it be properly utilized. I have had the belief for many years that the best way to utilize such tools, national facilities and national observatories, was to assure that the most creative and most imaginative scientists have access to them without regard to where they come from and that the selections be made on the basis of the science which had to be done.

Second, I believe very much in the competence and motivation of people who work for themselves on something they are very deeply interested in and therfore I feel that from a management point of view it is just right to have astronomers themselves take a hand in running their enterprise.

Given these premises, we are the people who are supposed to bring this about and I will try to discuss what we are doing about bringing these concepts to realization.

The first two conditions, namely, the availability of observing time through a competitive process, and management by the Scientist themselves are assured. There is no observing time selected in that competition except that which is devoted in the first 2½ years to the instrument teams. These teams were selected competitively on the basis of an open solicitation.

With respect to the rest of the time, which is most of the time, it is my responsibility to allocate time, and, of course, I will do that guided by the advice of a Time Allocation Committee and a Users Committee. However, there will be some time which is called discretionary time which is reserved either for operational problems or verifying performance of instruments, or to cope with proposals that do not easily fit in a peer review process and although I hope we will not give time to lunatics, we will support reasonable programs which could not be otherwise easily justified.

NASA has delegated a number of responsibilities to us. I would like to go through them very briefly. We are to establish a Space Telescope science program.

We believe that archival research, namely, research on data already acquired, will be an important component of the ST project.

We are to develop science observation procedures and capabilities, and integrate observers' schedules which we will give over to the operational control center, who will issue the actual commands.

We will act as a funding agency for U.S. users and will provide direct technical support to observers in preparation for the observations, during the observation and aiding them in work after the observations have been taken.

We are responsible for processing, for archiving and publicizing scientific data and we are supposed to make the information accessible not only to the scientific community, through scientific publications, but also through the media to the public.

We believe that diffusion of knowledge is an important consideration and we are spending quite a bit of attention and effort on that.

We are to become the right arm of NASA with respect to evaluating the scientific performance of ST and its individual instruments, or the system as a whole and we are to establish a competence whereby we can promptly advise them on these matters.

We must promote international participation beyond, of course, the integration of the European scientists within the program and we are encouraged to consider the Institute as an open structure, mainly something which is not divided from the astronomical community, but something to which scientists come and then return to their academic communities and vice versa.

This is actually happening in the sense that we have a fierce competition with major academic institutions as far as acquiring staff is concerned.

Finally, we are to support ST-related research which is necessary for the use of the observatory and in order to carry out all the above, of course, we can't do it without a highly competent scientific staff which, in order to retain its competence and to be attracted in the first place, must be allowed to carry out its own research program, and to this end each of the astronomers hired, is assured that he will have time for his own research.

About half of the time will be devoted be each astronomer to his own research interest.

We have been in existence for about a year. A number of senior positions have been filled, including, as you heard, the Director, the Deputy Director, the program manager, the business manager, and the chief data and operations scientist, which carries out a very important role in handling the vast amount of observation that we are required to process and distribute.

Many of the scientific positions are now being filled. The current total staff is 50 and includes 12 scientists. We expect a contribution of 10 additional astronomers from ESA which will occur over the next few years. The full staff at launch will be about 200, of which some 40 will be astronomers holding advanced degrees.

Therefore, the agency will certainly be no negligible research institute but will be quite comparable to some of the largest astronomical institutions in the world.

What we are trying to do is unprecedented: To get together in a very short time a group of scientists, to create a high quality astronomy department which will last for several years. So we have to exercise very great care in hiring the staff. We are doing this with all deliberate speed. We are using the best advice we can. We have created an ad hoc committee interviewing, identifying candidates, selecting them from the many, many requests for employment which we receive and I am satisfied that the people we are hiring are of a quality that would hold tenure in major academic institutions and in fact oftentimes they do.

Now, where are we? I already mentioned that we are at Johns Hopkins, a site which was selected together with the managing organization by NASA, on the basis of competitive proposals.

A new building is being built on a fast-track method and presumably will be ready for occupancy by May next year. I hope you will take an opportunity to come and visit it when we have opening ceremonies.

Now, the atmosphere in which ST ScI lives is very complicated. You saw all the charts showing our relationship to the rest of the world.

There are a number of interfaces. One has already been fairly well discussed; that is the one with the parent organization. We are not a separate independent legal entity, we are an operating arm of AURA, but we have responsibility for execution, whereas AURA, through its board, the Space Telescope Institute Council and the visiting committee has oversight responsibilities.

They carry out this oversight through a number of reports, visits, and plans which they have to approve.

Johns Hopkins has an important place in our interface. It does have students, which is an important consideration when we try to attract very high quality staff. They are accustomed to interacting with the school and we shall encourage that kind of interaction and therefore we will want to establish cooperative programs in which staff will hold courtesy appointments, appointments at nearby institutions and be allowed to teach and to supervise efforts by students.

The European Space Agency, of course, contributes to the program by furnishing hardware. It will furnish 15 members of the staff. It will furnish one of the instruments. It does participate by courtesy to the AURA committee and by right to the visiting committee.

This committee, of course, is what everybody has been discussing, Space Telescope Interstate Council and NASA's responsibility have been described previously.

There is a large number of interfaces and all of these interactions are regulated fairly strictly by fairly complicated, but necessary formal management tools. We are preparing a number of documents, management plans, design and test approaches, preliminary conceptual documents, and so forth, which are submitted by us and approved by NASA.

I don't intend to describe internal organization and structure, or the major tasks in which we are engaged except briefly.

A major task is to run the Institute itself, which is quite a time-consuming effort.

There are a number of activities which are expected from us and for which we have ultimate responsibility.

The development of a system whereby we plan the observations and make the observations available; the preparation of manuals and tests and users' guides for the general observers; the preparation of procedures for solicitations and then last but not least, of course, the preparation of a data management and dissemination system.

I thought I would say a few words about a specific task as an example and also because there was a question that I was given, about why do we need to do this work.

Well, the ST can point, as you heard, anywhere in space. Typically we want to point with very high accuracy and in order to do so we place within the field of view of the ST, some stellar object whose position is precisely known.

The field of view of the ST is not very large and therefore, in order to insure that, to that extent there will be stars whose positions are known within that field of view you need to know the positions of very faint stars because those are many and the chance that you find some in your field of view is very great and you want that chance to be 99 percent.

You need therefore to know the position of many faint stars, 10 million stars over the entire sky, and the stars we are interested in are as faint at 15th magnitude.

The normal catalogs go to eighth magnitude. These are fairly bright stars. The human eye can see a sixth magnitude star and we know the position of eighth magnitude stars in the sky. But for this mission we need to go 100 times fainter and therefore we have a program in which we are now measuring the position on the sky of sufficient stars so that anywhere at all we wish to point with ST we will have objects within the field of view.

It is not clear that we will have the entire catalog ready at the time of a launch. It is a very time-consuming process. Since we need to point the Telescope very accurately, we need to do these measurements with extreme care. In fact, with as much care as any astronometric measurement has been done. The difference here is that we need to do it over the entire sky as if it were a series production, so what we plan to do is to have this as complete as we can before launch, but to design the system in such a way that if we don't have it complete we will have a high enough throughput that for any set observation needed to be made on any particular day we can measure the stars that we need to know.

This is just one of the activities and I thought I would use it as an example to point out we are not just getting ourselves together and hiring each other and sitting around.

We are working as hard as we can. In fact, sometimes it seems too much and we are suffering a little bit and I hope after the initial case we can go back and maintain our sanity by doing at least some research.

Finally, I thought I would address points of concern, but I don't think I need to spend too much time on this because of the concerns that you yourself, Mr. Chairman, and members of the committee, have expressed, which I consider some kind of assurance that ST long term life will be preserved, and it is considered to be an important feature of the ultimate scientific performance.

I really believe that. I wrote it in my written testimony. Any reasonable man would think that after investing the kind of money we are investing in this facility we will try to run it as long as it makes sense to run it and we will use the considerable opportunity of the Shuttle to repair it, refurbish it and make sure it works and we will give the funds to scientists who can make best use of it.

On the other hand, sometimes budgetary requirements are such that I have seen important things being cut out of the program and in particular operation and data analysis activities being in jeopardy. That is why I thought I would express some concern.

Thank you.

[The prepared statement of Dr. Giacconi follows:]

Testimony
by
Riccardo Giacconi, Director
Space Telescope Science Institute
Subcommittee on Space Science and Applications
U.S. House of Representatives
24 May 1982

When flown in 1985, the Space Telescope (ST) will be the most powerful optical telescope available to astronomers in the next decade. Its unique capabilities derive from the fact that it will be placed above the obscuring and scattering effects of the Earth's atmosphere, thereby allowing the achievement of an unprecedented fine resolution and sensitivity.

ST is a general purpose observatory which will allow a variety of astronomical studies impinging on such disparate questions as the existence of planetary systems about other nearby stars and the early stages of formation of galaxies and clusters of galaxies in the remote past of our universe. Its increased sensitivity will allow us to explore a volume of the universe some 300 times greater then currently possible.

Once placed in orbit, ST will remain for many years one of the most important tools for scientific research available to man. It is important therefore that it be properly used. On the basis of previous experience with national facilities, it is clear that the best science gets done when: the use of the facility is open to the best and most imaginative proposals from scientists everywhere, and when the responsibility for managment of the facility is in the hands of the scientists themselves.

Both conditions are satisfied for ST. Over 70% of the observing time will be dedicated to competitively proposed observations selected on the basis of peer review. The remaining 30% of the time in the first two and one half years is devoted to use by the scientific groups responsible for the design and development of the initial set of instruments (these groups were also selected on the basis of open solicitation and competition).

NASA has delegated responsibility for scientific operations of ST to the newly formed Space Telescope Science Institute (ST ScI), an independent organization operated by the Association of Universities for Research in Astronomy (AURA) on behalf of NASA. ST ScI is the organization which is now working to translate these principles into successful practice.

The ST ScI will:
a) Establish ST science program guidelines and select ST observers and archival researchers.
b) Develop science observations, procedures, and capabilities and an integrated observing schedule for the operations control center.
c) Fund U.S. users and provide direct technical support to observers before, during, and after their observations.
d) Process, archive, and publicize ST scientific data making the information accessible to the scientific community and to the public.
e) Evaluate the performance of ST and its individual instruments and advise NASA on observatory status.
f) Promote international participation and conduct a program to encourage visiting scientists.

g) Sponsor ST-related research necessary for the efficient use of the ST observatory and establish a scientific staff of the first rank to perform all the above and conduct their own research related to ST.

The Space Telescope Science Institute has now been in existence for over one year. Most of the top management staff has been selected, including:

Director	Riccardo Giacconi
Deputy Director	Donald N. B. Hall
Program Manager	Adrienne Timothy
Business Manager	Vincent Severo
Chief Data and Operations Scientist	Ethan Schreier

Several of the scientists required to head the major developments have been selected. Total staff at the moment is about 50. Some 15 staff members will be provided by the European Space Agency (ESA) over the next two years. Full complement at launch is expected to be about 200.

Very great care is being exercised in the selection of the scientific staff with appointment procedures similar to those used at major universities. To aid me in this process I have established an ad hoc search committee of distinguished astronomers, broadly representative of the several disciplines in astronomy, which reviews applications and suggests and rank orders candidates.

The Space Telescope Science Institute will be located on the campus of The Johns Hopkins University in Baltimore, a site selected by NASA on the basis of competitive proposals. At the moment the staff is housed in temporary quarters placed at our disposal by Hopkins in the Physics and Engineering buildings. A new building is being constructed on campus to house ST ScI permanently. The groundbreaking ceremonies were held in September 1981; the building is expected to be ready for occupancy in May 1983.

In performing its tasks ST ScI interfaces with a number of organizations and groups that play an important role in the Space Telescope program. The parent institution (AURA) exercises oversight responsibility by means of annual approval of plans and by audits. It exercises additional oversight roles through the Space Telescope Institute Council (STIC) chaired by Professor Lyman Spitzer on a quarterly basis. A Visiting Committee will assess on a yearly basis the overall performance of the ST ScI and report to STIC, the AURA Board, and to the Associate Administrator for Space Science and Applications of NASA.

The Johns Hopkins University is the host institution and has academic relationships with ST through joint appointments regulated by AURA/JHU Memorandum of Understanding.

The European Space Agency will furnish 15 members of the ST ScI staff, provide one of the instruments for ST (the faint object camera) and will have representation on ST ScI committees as well as AURA committees (at AURA's discretion). ESA will receive copies of the ST data archives when the data is placed in the public domain.

The astronomical community has provided the full complement of scientists involved in the development of the ST Observatory and instruments. The general observers and archival researchers come from that community as will the scientists who will serve on the Users Committee and the Time Allocation Committee, advisory bodies to the Director of ST ScI.

NASA has overall responsibility for ST development, flight and operations. NASA provides the general goals and guidelines for the conduct of the ST program. It provides technical direction to ST ScI through the ST Program Offices at Marshall Space Flight Center and Goddard Space Flight Center.

These complex interactions require the use of formal management tools in the ST ScI operations. ST ScI prepares a number of formal documents, including monthly, quarterly, and annual reports, Management Plans, Design and Test approaches, Users and Training manuals, GO Solicitations and Reports, interface documents.

Our concepts and plans are subject to formal Preliminary and Critical Design Reviews, Program and Project Management Reviews, and Facilities Reviews.

In the interest of brevity I will not describe our internal organizational structure. I will, however, briefly indicate the major technical tasks in which we are currently engaged in addition to the obvious one of creating the Space Telescope Science Institute.

We are developing the capability to "run" the scientific observing program from the Space Telescope Science Institute. This requires the development of a Guide Star Selection System, development of Scientific Data Analysis Software, integration into the Science Operation Ground System (TRW), establishment of an interface with the Mission Operation Ground System (Lockheed, GSFC), development of in-house expertise about the ST Science Instruments, development of an operational capability, including proposal selection procedures and observational planning and scheduling procedures, development of data collection, reduction, and archival capabilities, and finally development of a data management and dissemination system.

As an example, I will expand on one of these activities: the development of a Guide Star Selection System. In order to point ST stars whose positions are precisely known must be acquired by the Fine Guidance Sensors. To insure that we may find stars of known coordinates and intensities everywhere in the sky, we need a complete catalogue of stars as faint as 15th magnitude. Such catalogues do not exist; those available stop at 8th magnitude. We are therefore obtaining a quick new photographic survey of the sky from Mount Palomar, Cerro Tololo, and Sacramento Peak Observatories. We have also obtained European Southern Observatory plates as well as plates from the United Kingdom. We measure the position of stars on these plates by means of measuring engines (Perkin Elmer PDS) controlled by computers (VAX 11/750).

Our aim is to obtain as complete a catalogue of stars to 15th magnitude as we can before launch with high accuracy positions (0.3 arc second) and good photometric accuracy. The system is being designed with high throughput so that new guide stars can be measured each day in a number sufficient to support the ST mission.

If you consider that this is only an example of the kind of activities in which we are engaged, you can readily perceive that we are busy as beavers in preparation for launch. After some initial starting pains we are moving into high gear to prepare ST ScI to carry on its functions and I am fully confident that we will succeed.

I was asked in the letter of invitation to express any concern I may have toward the future. I would express only one: It is clear that for Space Telescope to fulfill the high expectations of the scientific community its long-term stable performance must be ensured. This depends on the implementation of a sustained effort of mission operation and data analysis support as well as maintenance and refurbishment support over one or two decades.

Development of the Space Telescope Observatory itself is clearly receiving highest priority and attention right now as it must, but the ultimate success of the mission requires early technical and management planning of these support activities. Such planning is just now getting under way. Execution of these plans over the long term will require your continued interest and support over a span of years which is unusually long with respect to typical missions. Recent budgetary cuts precisely in these types of endeavors, in the mission operations and data analysis of astronomy and planetary missions already in orbit or in flight, give me some concern. This must not be allowed to happen for Space Telescope.

Mr. **Flippo**. Thank you very much for your testimony, Dr. Giacconi.

Doctor, the instruments are being developed by various teams. I am curious to know how you will insure that someone at the Institute is intimately familiar with the operations of the instruments?

In other words, how do you insure continuity of understanding the instruments? For example, how do you know they are accurately calibrated?

Dr. **Giacconi**. That is a major responsibility of the Institute. We are coping with that.

There are five fundamental instruments as well as a fine guidance system which is an instrument all in itself.

Our plan includes hiring two scientists responsible for each of the instruments. These scientists, typically a junior and senior scientist, particularly the senior scientists, tend to be members of the development team. We have now three aboard who were involved in the development of the instruments themselves and have chosen to come to the Institute; they contribute an intimate knowledge about the instruments. This group of 12, plus a leader and plus support, will be our repository of knowledge, not only for the instruments applied in the first flight, but also by extension of the learning process about future instruments NASA may select.

Further, they will advise on what other instruments would be useful in the future as well as how these instruments are being used.

Mr. **Flippo**. Mr. Brown?

Mr. **Brown**. Let me say first, gentlemen, that I consider it a privilege for the subcommittee to have two such distinguished scientists here to brief us on this project.

I am sort of a closet astronomer. I wouldn't get an opportunity to talk to gentlemen such as yourselves in the normal course of my activities. I enjoy this opportunity very much.

Getting back to a question I asked earlier, without very much thought, but in reflection, I am still a little concerned as to the pointing and tracking system that you use.

You have to compensate for several sets of motion in the orbiting instrument and I am still not quite sure how you do it. Could you give me a quick explanation of that?

Dr. **Spitzer**. The general theory that is being followed is the same as has been followed on previous satellites, particularly the Copernicus satellite where I was the principal investigator.

The theory is, if you spin a wheel a little faster in one direction, the telescope moves in the opposite direction and you use that in the first instance to provide the torque that keeps the telescope moving in whatever direction you need to move it.

Then you look at some stars very precisely on crosshairs, so to speak, to make sure that the telescope is really pointing very accurately in a constant direction. You then use the wheels to keep it pointed there.

Mr. **Brown**. You can keep it pointed precisely in the same direction?

Dr. **Spitzer**. Yes.

Mr. **Brown**. You are photographing these stars so you need to focus on them for what period of time?

Dr. **Spitzer**. Up to 10 hours. Fred Speer ought to mention this since he is really the person——

Mr. **Brown**. I presume the precision of the motion varies with the star you are focusing on. If it is a remote distance little things like motion around the Earth won't make any difference.

Dr. **Spitzer**. They are all far enough away so that motion around the Earth——

Mr. **Brown**. Motion around the Sun——

Dr. **Spitzer**. In 10 hours that doesn't affect you much.

Mr. **Brown**. It is still a delicate problem?

Dr. **Spitzer**. There is the aberration of light that has to be taken into account and there are many complications.

Mr. **Brown**. Now we have a little problem in astronomy that is shared by a number of the physical sciences in that we are producing more people in some areas than we have available positions—at least tenured university positions—to fill.

I am wondering if this whole operation is going to have any impact on the employment prospects for bright young astronomers coming out of universities?

Dr. **Giacconi**. It will in the sense that although we do not have tenure positions in the sense that the university has tenure positions because they have endowment funds, we have tenure to the extent there are funds available in the contract which hopefully will run for 20 years.

Mr. **Brown**. Aside from the funds I am assuming there will be enough funds to operate the instrument and reduce the data and do the analysis and so on. I don't know what the volume of work in relationship to the existing stream of data coming from other observatories is, but I would assume it would have a measurable influence.

In other words, you would need at least some increase in the body of skilled observers and analysts who could begin to digest all this large new stream of data into new scientific theories.

Dr. **Giacconi**. That is very true.

Mr. **Brown**. I am trying to see if there is a grasp of that. As a follow-on, both of you have suggested there is going to be a lot more demand for observing time than may be available and the logical question that comes to mind is, do we have to stop at one instrument?

We didn't with ground-based astronomy. Is there any particular reason why the Europeans couldn't have an instrument, the Japanese have an instrument, other scientific communities that felt this was a promising area have an instrument, and whoever is involved could be marketing hardware for additional instruments.

Has that been contemplated at any point or is it felt this would meet our needs for the next 20 years?

Dr. **Giacconi**. The answer is no. There has been a recent review by the National Academy of Sciences in which the needs have been contemplated and there is a recommendation for additional facilities. I think the unfortunate point is that the cost of this facility is so large that really one could scarcely consider that they could be built with private funds.

Mr. Brown. What are we talking about, a half billion dollars?

Dr. Giacconi. That is the kind of thing we are talking about and therefore they do tend to require public funds.

Mr. Brown. Isn't a lot of that cost first-time costs that might not be quite as high for the second or third instrument?

Dr. Spitzer. I would be glad to hear Fred's estimate on how much a second telescope would cost at the present time.

Mr. Speer. You would never build it identical. It would cost a lot less if you could build it fairly soon. If you had several years coming in between you would have to start developing certain components all over again.

You have the fine guidance and the state of the art doesn't stand still. We could not use even the exact same elements. It would certainly be less. My guess would be, it would be about half if we did it right away, but we have already passed that point in time.

Many of the things would not be used again.

Mr. Brown. I don't know of all the components involved in this telescope, but some of it is off the shelf that has been built repeatedly before.

It seems to me reasonable that a second Space Telescope might be in constant dollars only half the cost of the first one if the demand is there for such an instrument, and we had an affluent community willing to support it.

Dr. Giacconi. I think the statement you make is absolutely correct. I think that space is where astronomy is going to be done. There are a number of things being proposed. I don't think there is lack of creative imagination and demand. I think there is just a sobering realization that there is a finite amount of money that can be used. The enthusiasm is there.

Mr. Brown. I can't imagine the Chinese wanting to let us take the lead in astronomy when they were leaders for so many centuries before us.

Dr. Giacconi. They are interested in participating in the Space Telescope Institute and in using the Space Telescope.

Mr. Brown. You are not precisely sure of what the demand for observing time will be at this point?

Dr. Giacconi. I directed the Einstein Observatory.

Mr. Brown. He was not an astronomer, was he?

Dr. Giacconi. No, but he had something to do with general relativity.

This was an excellent Telescope built as a principal investigator's telescope. The annual users group came to 375 guest observers using half the time of that facility. The typical level of observers at a typical observatory is something like 700 per year so we are talking about very large numbers and I think the rate of over-subscription which is known to occur is on the order of two or three.

Mr. Brown. This committee frequently gets concerned about the possibility for our American science and technology to supply needs on a worldwide basis. I raise the question for that reason.

This is a large, expensive instrument. It may well be that it represents not only a scientific opportunity, but a commercial opportunity that would be worth exploring for many American firms.

Let me ask one additional question. One of my interests has been with the plight of the poor astronomers who have no place to abserve and who go out and build their own observatory. I am thinking of MIRA in this regard with which you are probably familiar and other amateurs who have made contributions to astronomy but are not associated with any reputable institution.

Is there some cognizance given to the possibility that gifted amateurs or even gifted professionals not affiliated with universities might want to make use of these facilities and could be accommodated?

They would be welcome, I presume, to submit proposals and have them screened on the same basis as others?

Dr. GIACCONI. Perhaps I could respond. Rather than making a statement of intent, I will tell you what did happen, for instance, with respect to the Einstein Observatory. It turns out that some X-ray stars are extremely variable and the Association of Viable Star Observers which, as you know, is one of the strongest associations in the United States, became very, very interested. What we did was to hold symposia, and workshops in Cambridge, Mass., where we invited representatives of this group. They in fact did become involved and we set up joint programs of observation in which peer reviewed scientists, used the very valuable time of the telescope but then collaborated in a program with the amateur astronomers who supplemented them with the data that they could get. That was very interesting and I think a very alive type of thing.

In addition to that, of course, with respect to the not amateurs, but young professionals, one of the goals in our charter is to conduct a program to encourage visiting scientists. We mean that very definitely and we will have a program of post docs which will be limited essentially by available funds and visiting scientists, again limited by available funds.

It will be significant though. Four post docs will be appointed every year and perhaps 2 years and four visiting scientists per year, who will come and go and be a part of the——

Mr. BROWN. Four seems like an awfully small number, considering the large number of——

Dr. GIACCONI. All I can tell you is, since my accession as director, I doubled that number. That number I reported is a doubled number.

Mr. BROWN. When we have more time, I would like to explore with you the potential that the Institute has, not only for professional training at the post-doctoral level, but for public education in science and astronomy in particular, which is extremely fascinating right now.

I imagine you might be amazed at the number of amateur astronomy groups all around this country who are vitally interested in enlarging their own area of knowledge.

This new instrument could become a challenge, a real stimulus to increased interest in science on the part of an enlightened public.

Dr. GIACCONI. I think you have a very correct point and I would be delighted to sit down and discuss it with you.

Dr. SPITZER. I believe the tremendous amount of data that will be available in the archives after a few years will be a tremendous resource for anybody with an interest in astronomy who would like to do various types of research. These will be generally available.

Mr. FLIPPO. Thank you.

I did have one final question. In your testimony you talk about astronomers staking out various portions of the sky for particular observations. Do you expect that to lead to complaints from the scientific community that you are censoring scientific data that should be made public information? How do you do that?

Dr. SPITZER. That is one of the policy questions that we are going to consider. Anybody who submits a proposal and has it approved has in some sense a certain reservation for a particular star to be observed on a particular wave length for a year or so after the data will be obtained and the instrument definition teams, their guarantee will last a little longer, but that also will expire in time.

Mr. FLIPPO. Can the Telescope make radio observations?

Dr. SPITZER. No.

Mr. FLIPPO. Gentlemen, thank you so very much for your testimony. It has been extremely helpful to us.

Our final witness today is Robert D. Williams, vice president and general manager, Software and Information Systems Division, TRW.

We are delighted to have you with us. You might introduce the gentleman at the table with you and proceed as you deem appropriate.

STATEMENT OF ROBERT D. WILLIAMS, VICE PRESIDENT AND GENERAL MANAGER, SOFTWARE AND INFORMATION SYSTEMS DIVISION, TRW, INC., ACCOMPANIED BY ROBERT A. BAIN, PROJECT MANAGER, DEFENSE AND SPACE SYSTEMS, TRW, INC.

Mr. WILLIAMS. I appreciate the opportunity to present testimony here today on TRW's involvement with the Space Telescope program. We are very excited to be a part of this program and worked very hard to get to be a part of this program.

I would like to introduce the gentleman on my right, Bob Bain, the program manager of the SOGS effort at TRW.

I would put my remarks into three areas.

First, exactly what our role in the program is. Second, my assessment of the risk and problems involved in fulfilling that role.

Finally, an explanation of how we have successfully interacted with the Space Telescope Science Institute and our plans for future cooperation.

The Space Telescope program consists of many elements. The element called the science operations ground system, is responsible for science planning and scheduling, selecting the experiments to be performed by the Space Telescope; target acquisition, insuring that the instruments are properly alined for data capture; science instrument and data quality evaluation, verifying that the data being collected satisfies experiment objectives; science data calibration, editing and archiving, systematic filing of the data collected for later retrieval and analysis, and science data product generation, creation of photographs and computer tapes of interesting results.

Under a competitive contract awarded by NASA in December 1981, TRW is to design, develop, integrate and test the hardware and software necessary to perform these functions. We are to install the completed system at the Science Support Center at Goddard Space Flight Center and at the ST Science Institute facility at Johns Hopkins University.

We are to operationally train personnel, prepare user manuals, and support an efficient transition from our development to operational control by the ST Science Institute.

The science requirements have been developed by the Space Telescope mission operations working group for the past 3 years. These requirements formed the basis for the functional specification which NASA issued with its request for proposal and on which we based our successful response.

Upon delivery, the ST Science Institute will be responsible for the science program including the operation and management for the science operations ground system.

This organization is also responsible for the guide star selection system and the development of the science data analysis software which will be integrated and executed within SOGS.

Developing SOGS is not a new and unique task for TRW. We built the first interplanetary spacecraft, Pioneer 1. Since then we have built more than 150 spacecraft, integrated over 550 experiments, and accumulated more than 320 spacecraft years of on-orbit operation.

Working closely with the scientific community, we have designed, integrated, and tested more than 200 instruments and clocked more than 2,175 experiment years of orbital data.

TRW has twice received the Nelson P. Jackson Award for outstanding contributions to the space field.

Three of our systems in particular that related to SOGS are the tracking data relay satellite system, EROS digital image processing system, and the ground-based electo-optical deep space surveillance system.

The tracking data relay satellite system will handle the flow of data between NASA control centers and NASA user spacecraft. It will relay data to and from the Space Shuttle, unmanned Earth-orbiting spacecraft, and a major ground station at White Sands, N. Mex.

Our ground system portion of this program involves the networking of 11 computers into an integrated whole.

For the EROS data center of the Department of Interior, we designed, integrated and installed a system to process imagery from the Landsat satellites. Our system was delivered on time without any cost overrun.

For the Air Force we designed, manufactured, and installed a computerized system to convert images from optical telescopes into electronic signals that can be processed and transmitted in real time to the Air Defense Command. This effort recently received the award as contract of the year from the Air Force Electronics System Division for our outstanding accomplishment.

Our success in these programs and others like them give us the confidence that the science operations ground system will proceed to a successful conclusion.

As I am sure you are aware, the Space Telescope itself represents an exciting challenge for American Government and industry. State of the art techniques are being employed to develop the space borne platform, optics, and five instrument packages for the initial payload.

For the science operations ground system, however, our design calls for the use of off-the-shelf commercially available computer and peripheral components. A requirements specification is needed only for some of the communication hardware that will link the Science Support Center at Goddard with the ST Science Institute facility at Johns Hopkins. Almost all of the hardware to be employed in SOGS will have already been tested in other applications.

With the exception of some of the activities concerned with target acquisition, data evaluation and the communications between facilities and computers, the software that we will develop for the science operations ground system will be of a type called nonreal time.

This type of software is easier to develop, test, and integrate than the real-time software that dominates some of the more complex NASA and Department of Defense systems.

Because of these considerations, in my opinion the science operations ground system represents less risk than those we encountered in, for example, the three successfully developed systems that I have mentioned above.

Now, of course, no development of the size of SOGS is totally without some risk. We are working to a tight schedule. We have interface complexities with other elements of the Space Telescope program. Processing requirements for the instruments could change as they evolve and mature. But these risks do not represent fundamental limitations in what we are trying to do.

No breakthrough in the state of the art is required. These system development risks are precisely the reason we are involved with the program. We have the skills, the people, the experience, with other systems of this type to manage them and control their impact.

In summary, I foresee no major difficulties in producing in a timely fashion a science operations ground system that will be reliable and responsive to the scientist's needs.

As I have mentioned above, TRW has been on contract with NASA for some 5 months. Our focus to date has been upon developing and understanding the detailed requirements for SOGS so that all concerned can be assured of the utility of the final product.

As part of the process, we have two explicit contractual deliverables which specify the interfaces between what we are developing for the ST Science Institute and other components they are developing themselves.

By this mechanism we can insure that our part of the science operations ground system, the guide star selection system, and the science data analysis software will all play in harmony when they are brought together.

We are also required to review the requirements, development and test documents that the Institute is preparing for the developers of the science data analysis software.

This will insure compatibility in development standards and data interfaces. As part of our contract with NASA, we will integrate a representative set of the science data analysis software with our system.

Besides formal documentation and review, NASA has invited Institute personnel to attend all of our technical interchange meetings including those with each of the groups developing the five instruments for the satellite.

Institute personnel have been present and will continue to be invited to all of our interface, requirement, and reviews with NASA. This free access to information will greatly enhance the interchange of ideas and clarification of concepts.

We have reviewed two drafts of the science operations concept prepared by the ST Science Institute and have used this material in defining requirements and approaches for SOGS. We have identified to NASA those concepts which are presently out of scope of our contract. NASA has collected these requirements and following them, our preliminary requirements review will direct us how to proceed in a manner consistent with budget constraints and cost consciousness.

In summary, I feel that our working relation with the ST Science Institute and the scientific community is a good one. Explicit mechanisms are already working to ensure that their needs are satisfied. We are committed to producing a quality product that the Institute will use with pride.

[The prepared statement of Mr. Williams follows:]

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Robert D. Williams
Vice President and General Manager
Software and Information Systems Division

As Division General Manager, Mr. R. D. Williams is responsible for the design and development of systems for mission data processing, mission planning and control, and for electronic information systems.

In 1979 Mr. Williams was appointed Assistant General Manager for Projects of the Systems Engineering and Integration Division, consisting of 4,000 people and 170 projects. In this capacity he was responsible for the performance of all projects and for the division's data processing and software support to TRW Defense and Space Systems Group. Mr. Williams was also Chief of the Software Productivity Team which generated advanced management tools and concepts for modern software development, tailored for computer networks.

From 1970 to 1975, Mr. Williams was Program Manager for Software Development of the U. S. Army's Site Defense Program. This $100 million software development program was completed on time and under cost. New management techniques were pioneered which led to current TRW software development policies.

After joining TRW in 1969, Mr. Williams managed the Defense and Space Systems Group's Requirements and Analysis organization, directing studies of advanced weapons and performing strategic concept analyses.

Mr. Williams' prior experience includes service with the SAFEGUARD System Evaluation Agency, U. S. Army where he was Director of Evaluation. He also managed the design and development of instrumentation and missile systems and designed nuclear tests for a number of DoD programs.

Mr. Williams received a B.S. in Electrical Engineering from Texas A&M University in 1954. He is a member of the Operations Research Society, American Institute of Aeronautics and Astronautics, and the Association of the U. S. Army. Mr. Williams has authored a number of technical reports in the field of energy conservation, program management of software and strategic weapon systems analysis and evaluation. He is a consultant and instructor of software development methodology for NSA and within TRW. He is the author of a chapter, "Management of Software Development," in C. R. Vick's "Handbook on Software Engineering."

May 1982

TESTIMONY OF
ROBERT D. WILLIAMS
VICE PRESIDENT AND GENERAL MANAGER
SOFTWARE AND INFORMATION SYSTEMS DIVISION
TRW DEFENSE SYSTEMS GROUPS
REDONDO BEACH, CALIFORNIA
BEFORE THE SUBCOMMITTEE ON
SPACE SCIENCE AND APPLICATIONS
HOUSE SCIENCE AND TECHNOLOGY COMMITTEE

24 MAY 1982

Mr. Chairman, Members of the Subcommittee on Space and Science Applications:

I appreciate the opportunity to present testimony here today on TRW's involvement with the Space Telescope program. We are excited about being a part of the quantum leap in our ability to study and understand the universe.

I would like to focus my remarks into three areas. First, a definition of exactly what is TRW's role in the program. Second, my assessment of the risks and problems involved in fulfilling that role. Finally, an explanation of how we have successfully interacted with the Space Telescope Science Institute and our plans for future cooperation.

TRW's role

The Space Telescope Program consists of many elements. The element called the Science Operations Ground System (also known as SOGS) is responsible for:

- science planning and scheduling — selecting the experiments to be performed by the Space Telescope
- target acquisition — ensuring that the instruments are properly aligned for data capture
- science instrument and data quality evaluation — verifying that the data being collected satisfies experiment objectives
- science data calibration, editing, and archiving — systematic filing of the data collected for later retrieval and analysis
- science data product generation — creation of photographs and computer tapes of interesting results.

Under a competitive contract awarded by NASA in December of 1981, TRW is to design, develop, integrate and test the hardware and software necessary to perform these functions. We are to install the completed system at the Science Support Center at Goddard Space Flight Center and at the ST Science Institute Facility at Johns Hopkins University. We are to operationally train personnel, prepare user manuals, and support an efficient transition from our development to operational control by the ST Science Institute.

The science requirements have been developed by the Space Telescope Mission Operations Working Group for the past three years. These requirements formed the basis for the functional specification which NASA issued with its request for proposal and on which we based our successful response.

Upon delivery, the ST Science Institute will be responsible for the science program including the operation and management for the Science Operations Ground System. This organization is also responsible for the Guide Star Selection System and the development of the Science Data Analysis software which will be integrated and executed within SOGS.

Developing SOGS is not a new and unique task for TRW. We built the first interplanetary spacecraft, *Pioneer 1.* Since then we have built more than 150 spacecraft, integrated over 550 experiments and accumulated more than 320 spacecraft years of on-orbit operation. Working closely with the scientific community, we have designed, integrated and tested more than 200 instruments and clocked more than 2,175 experiment years of orbital data. TRW has twice received the Nelson P. Jackson Award for outstanding contributions to the space field.

Three of our systems in particular that related to SOGS are the Tracking Data Relay Satellite System, EROS Digital Image Processing System, and the Ground-Based Electo-Optical Deep Space Surveillance System.

The Tracking Data Relay Satellite System will handle the flow of data between NASA control centers and NASA user spacecraft. It will relay data to and from the Space Shuttle, unmanned earth-orbiting spacecraft, and a major ground station at White Sands, New Mexico. Our ground system portion of this program involves the networking of eleven computers into an integrated whole.

For the EROS Data Center of the Department of Interior we designed, integrated and installed a system to process imagery from the *Landsat* satellites. Our system was delivered on time without any cost overrun.

For the Air Force we designed, manufactured, and installed a computerized system to convert images from optical telescopes into electronic signals that can be processed and transmitted in real-time to the Air Defense Command. This effort recently received the award as contract of the year from the Air Force Electronics System Division for our outstanding accomplishment.

Our success in these programs and others like them give us the confidence that the Science Operations Ground System will proceed to a successful conclusion.

Risk Assessment

As I am sure you are aware, the Space Telescope itself represents an exciting challenge for American government and industry. State-of-the-art techniques are being employed to develop the space borne platform, optics, and five instrument packages for the initial payload.

For the Science Operations Ground System, however, our design calls for the use of off-the-shelf commercially available computer and peripheral components. A requirements specification is needed only for some of the communication hardware that will link the Science Support Center at Goddard with the ST Science Institute Facility at Johns Hopkins. Almost all of the hardware to be employed in SOGS will have already been tested in other applications.

With the exception of some of the activities concerned with target acquisition, data evaluation and the communications between facilities and computers, the software that we will develop for the Science Operations Ground System will be of a type called non-real time. This type of software is easier to develop, test and integrate than the real-time software that dominates some of the more complex NASA and Department of Defense systems.

Because of these considerations, in my opinion, the Science Operations Ground System represents less risk than those we encountered in, for example, the three successfully developed systems that I have mentioned above.

Now, of course, no development of the size of SOGS is totally without some risk. We are working to a tight schedule. We have interface complexities with other elements of the Space Telescope Program. Processing requirements for the instruments could change as they evolve and mature. But these risks do not represent fundamental limitations in what we are trying to do. No breakthrough in the state of the art is required. These system development risks are precisely the reason we are involved with the program. We have the skills, the people, the experience with other systems of this type to manage them and control their impact.

In summary, I foresee no major difficulties in producing in a timely fashion a Science Operations Ground System that will be reliable and responsive to the scientist's needs.

Our Working Relation with the ST Science Institute

As I have mentioned above, TRW has been on contract with NASA for some five months. Our focus to date has been upon developing and understanding the detailed requirements for SOGS so that all concerned can be assured of the utility of the final product.

As part of the process we have two explicit contractual deliverables which specify the interfaces between what we are developing for the ST Science Institute and other components they are developing themselves. By this mechanism we can ensure that our part of the Science Operations Ground System, the Guide Star Selection System, and the Science Data Analysis Software will all play in harmony when they are brought together.

We are also required to review the requirements, development, and test documents that the Institute is preparing for the developers of the Science Data Analysis Software. This will ensure compatibility in development standards and data interfaces. As part of our contract with NASA we will integrate a representative set of the Science Data Analysis Software with our system.

Besides formal documentation and review, NASA has invited Institute personnel to attend all of our technical interchange meetings including those with each of the groups developing the five instruments for the satellite. Institute personnel have been present and will continue to be invited to all of our interface, requirement, and reviews with NASA. This free access to information will greatly enhance the interchange of ideas and clarification of concepts.

We have reviewed two drafts of the Science Operations Concept prepared by the ST Science Institute and have used this material in defining requirements and approaches for SOGS. We have identified to NASA those concepts which are presently out of scope of our contract. NASA has collected these requirements and following them, our Preliminary Requirements Review will direct us how to proceed in a manner consistent with budget constraints and cost-consciousness.

In summary, I feel that our working relation with the ST Science Institute and the scientific community is a good one. Explicit mechanisms are already working to ensure that their needs are satisfied. We are committed to producing a quality product that the Institute will use with pride.

Mr. FLIPPO. Mr. Williams, thank you very much.

Mr. Brown.

Mr. BROWN. Mr. Chairman, I don't have any detailed questions but just as a general matter, you referred to your Air Force contract to convert the images from the optical telescope into electronic signals. Will that system be used in the Space Telescope?

Mr. WILLIAMS. No, sir. It is used for identifying—for finding and identifying satellites in Earth orbit, whether launched by us or any other party.

Mr. BROWN. What is the system for getting the images back from the Space Telescope? Are normal photographs made with the Space Telescope and then trasmitted back?

Mr. BAIN. Well, it is readout of storage devices each instrument has which is then read out and sent through the down link, digital data.

Mr. BROWN. It is all digital data?

Mr. BAIN. Yes, sir. Digitally transmitted.

Mr. BROWN. You don't, however, develop a system for scanning an actual photograph and sending it back to Earth?

Mr. WILLIAMS. No.

Mr. BAIN. There is no film, no.

Mr. BROWN. I think I know what you are talking about.

Mr. FLIPPO. How much of the science operations ground system will be at Goddard and how much at the Institute?

Mr. WILLIAMS. In a hardware sense, about a third of it is at Goddard and about two-thirds at the Science Institute.

A majority of the software is built for the Science Institute, but it could reside anywhere.

Mr. **Flippo**. I believe you testified most of the hardware was off the shelf?

Mr. **Williams**. Yes.

Mr. **Flippo**. Is there a fixed price contract?

Mr. **Williams**. No, sir.

Mr. **Flippo**. Should it be?

Mr. **Williams**. No, sir.

Mr. **Flippo**. Why not?

Mr. **Williams**. Well, we believe that as the instruments develop and as there are changes in the concept of operations at the ground station, that we need to adapt to the changing requirements to make sure the ground station is useful.

Of course, I will say, sir, if this contract had been competed on a fixed price basis, TRW would have still bid the contract.

Mr. **Flippo**. We appreciate very much your testimony and we look forward to a successful operation of the ground system.

Mr. **Williams**. Thank you, sir.

Mr. **Flippo**. I want to thank all of our witnesses for appearing today.

We will have a meeting at 9:30 tomorrow morning here in this room and thank all of you for coming.

[Whereupon, at 3:50 p.m., the subcommittee was adjourned.]

OVERSIGHT: 1982

SPACE TELESCOPE

TUESDAY, MAY 25, 1982

House of Representatives,
Committee on Science and Technology,
Subcommittee on Space Science and Applications,
Washington, D.C.

The subcommittee met, pursuant to call, at 9:30 a.m., in room 2325, Rayburn House Office Building, Hon. Ronnie G. Flippo (chairman of the subcommittee) presiding.

Mr. Flippo. Good morning. The subcommittee will come to order.

On this second day of our hearings on the Space Telescope, we are going to focus on the development of the telescope since we covered the Science Institute yesterday.

Development of this orbiting telescope continues to be a major technical challenge which NASA and industry have met quite well. We realize the difficulty of the job NASA has taken on. Today, we want to look into the budget, management, and schedule history of this project. As we begin, let me say that the project seems to be basically sound, and what we want to do is to insure that the lessons learned in this project are documented and made part of NASA's future management procedures. Already, we are hearing about the AXAF which will also be a large development and we want to make sure it proceeds very smoothly.

Thus, we want to know the how, when, and why of questions such as: Has the launch date slipped? Has the budget grown? Have performance standards changed?

For example, the project organization chart presented at a similar hearing in 1978 differs from the one presented today, and we would like to understand these differences.

Unfortunately, Mr. Hollenbeck, the ranking minority member, was unable to be with us today. We do have his opening statement and, without objection, it will be inserted in the record at this point.

[The opening statement of Mr. Hollenbeck follows:]

Opening Statement by Hon. Harold C. Hollenbeck

Thank you, Mr. Chairman. The Space Telescope project represents the new type of spacecraft that are STS-compatible. By its modular design, the observatory can be revisited for repairs as well as upgrading.

The Space Telesacope is one of the very few ongoing civilian space programs we have today. In recent years, we have seen the cancellation of the Venus Orbiting

Imaging Radar, the two-spacecraft International Solar Polar Mission, Halley Comet Intercept Mission, and the expensive reversal of what upper stage to use for the Galileo and planned ISPM. Many people are counting on the success of the Space Telescope and its operation through the Space Telescope Science Institute to push modern astromony far and beyond its current capabilities, as well as feed valuable data into the stagnated planetary exploration program.

The Space Telescope represents state-of-the-art technology in a number of areas. Not only is the design approach unique, but the Perkin-Elmer optical system and pointing system are the finest and most accurate available today. The Space Telescope will also be compatible with the soon-to-be-launched Tracking and Data Relay Satellite System.

Mr. Chairman, I look forward to the testimony of our witnesses today who will report on the progress of the Space Telescope.

Mr. Flippo. We are pleased to have all of our witnesses with us.

Would the gentleman from California care to make an opening statement?

Mr. Brown. No, thank you, Mr. Chairman.

Mr. Flippo. Our first witness is Dr. Franklin D. Martin, Director of the Astrophysics Division, Office of Space Science and Applications. We are delighted to have you with us. Please feel free to summarize and proceed as you deem appropriate.

STATEMENT OF DR. FRANKLIN D. MARTIN, DIRECTOR, ASTROPHYSICS DIVISION, OFFICE OF SPACE SCIENCE AND APPLICATIONS, NASA, ACCCOMPANIED BY FRED A. SPEER, MANAGER, SPACE TELESCOPE PROJECT OFFICE, MARSHALL SPACE FLIGHT CENTER

Dr. Martin. Again, it is a pleasure to be here this morning. I would like to thank the chairman and members of the subcommittee for their kind attention yesterday. I know these are busy times.

If I could have the first chart, please. Today, we show the telescope [Chart A] looking in the opposite direction. The reason will become apparent shortly. We will be discussing the space segment of the program today, and following me will be the two associate contractors, Lockheed and Perkin-Elmer, with their discussions. I am sure they are going to go into much more detail in terms of highlights and progress and into some of the technical difficulties that we have been through together over the past several years. I will try to keep my comments brief.

I think I may be able to address some of your questions with this chart.

First of all, the organization [Chart 1] for the Space Telescope has not changed since 1978, except for the addition of the Space Telescope Science Institute.

What I did here in terms of chartsmanship is to simplify and combine a few terms, just to keep things from being so complicated on the chart. I apologize to the chairman for that.

You will see the additions are the Science Institute participation, which I discussed yesterday, under the European Space Agency [ESA] and, of course, the Science Institute under Goddard Space Flight Center. I have elected to call out the management responsibilities of Marshall Space Flight Center, including the maintenance and refurbishment. I would like to begin at the top of the chart to point out that Marshall Space Flight Center is the project management center for the Space Telescope and, as such, is responsible for the total maintenance and refurbishment activity, which include more than just the science instruments. Refurbishment or replacement of science instruments is a key part of the Space Telescope science program. There are other elements of this observatory, which must also be updated, such as batteries, and gyros as well as other components. So, the total system responsibility for maintenance resides at Marshall Space Flight Center. We expect that it will remain at Marshall through the life of the program.

Mr. FLIPPO. Dr. Martin, when do you anticipate transferring the responsibility from Marshall to Goddard? I guess Goddard has operations responsibility.

Dr. MARTIN. That is right, sir. In this sense, Goddard has the responsibility for operations right now. As I pointed out, this is a Marshall project. We expect that there will continue to be a Marshall project manager throughout the life of the program, but the emphasis on the operations will be at the Goddard Space Flight Center. We will be ready at launch for the operations.

The first two big checks here simply refer to two associates that you will be hearing from later. I believe that they will be discussing the other elements of the program.

The solar arrays and the faint object camera are provided by ESA. For the purposes of reporting into the project, there is a direct ESA interface with the Project Manager, Fred Speer. There is also an ESA person located at Goddard that coordinates the interface between the faint object camera and the other science instruments for which Goddard is responsible. ESA's instruments are treated just as the U.S. instruments are.

Mr. FLIPPO. Dr. Martin, who will have responsibility for the second generation of these instruments? Do you anticipate the Science Institute developing new instruments or refurbishing these instruments?

Dr. MARTIN. I think I mentioned yesterday that our current concept for the Institute does not involve hardware development. We have institutions, both NASA institutions and universities, that are capable of developing second-generation instruments. I think we have to look very carefully at how we allow the Institute to grow, whether it becomes a hardware-building center to compete with others in these tight times, or whether it simply continues to be an operational center.

Mr. FLIPPO. But, at the present time, you do not anticipate it?

Dr. MARTIN. That is a decision we will have to make.

The relationship with Johnson Space Flight Center and Kennedy ties into our ability to maintain and refurbish the spacecraft, and they will handle the operational aspects of that, involving crew and others.

Are there any questions about this particular chart?

I am going to leave this schedule—Chart 7—up. Some of it you are familiar with. What I will try to do through the remainder of the discussion, to the extent possible, is follow a color code to assist you in going through this, and to talk about the three elements of the program.

The yellow indicates the science instruments; the pink is the support systems module, which is the Lockheed part of the program; and the green shows the optical telescope assembly which is under Perkin-Elmer.

We discussed the mission operations and data analysis yesterday. I only call your attention to the science operations ground system [SOGS] activities and the preliminary design review [PDR's] and critical design review [CDR's] that are upcoming on that. Mission operations ground system readiness is projected for the first part of calendar year 1985, and that is our target for launch.

I will not say anything about the command and data-handling system. That is part of the Goddard activities; however, it is moving along well and is part of the system that supports the science instruments.

This is the high speed photometer chart 2. This chart shows the high resolution spectrograph, the high speed photometer, the faint object spectrograph, the faint object camera, and the wide-field planetary camera. We have basically two cameras—two spectrometers and one photometer. Shown is the actual flight hardware that the University of Wisconsin has provided which will be shipped in the near term to Goddard for some preliminary testing. It will ultimately wind up being put into the verification and assembly program at Goddard with the rest of the instruments prior to shipment to Lockheed for integration into the total spacecraft. We have had problems with the science instruments. I would like to point out that the cost growth and the schedule extension associated with this program have occurred in all three of the areas highlighted. It is not just in one area that we have had problems.

The high speed photometer is the simplest instrument, and we have had little or no difficulty with it. But, I think, virtually all of the other instruments have had problems with the detector development or electronics developments that have caused cost growth.

Chart 3 shows the primary mirror for the telescope. It is one of the finest optical systems that has ever been put together. It did take us months or more to do this than we had planned, which contributed directly to much of our schedule problems and our difficulty in getting the job done. I will come back to this later.

I would like to discuss this mirror. It is described as diffraction limited, having a surface quality of one-millionth of an inch variation if you were to look across that total surface is 94 inch is. To put that in a different perspective, if one could take that mirror and enlarge it with its current surface structure and if you could enlarge that mirror to a diameter that was from here to Denver, the variation in that surface would be only an inch. So, it is an incredible achievement in terms of optical quality, and it exceeds the specifications for the telescope.

Chart 4 shows the metering truss and the main ring which holds that mirror. We also have to have a fine guidance system and a pointing control system that can point this mirror very accurately, because it doesn't help to have the best instrument in the world if you can't point it very accurately.

The stability requirements are 0.007 arc seconds in terms of our goal. I believe that the system that we have right now assures us of 0.008 arc seconds. Our commitment to the science community is 0.012 arc seconds. An arc second can be described as follows: If you could hold a dime at arm's length and hold it up to the sky, the angle which could be blocked out with that dime, looking from the eye to the dime, would be equivalent to about 2,000 arc seconds. In order to be competitive with the Space Telescope in terms of stability, one would have to be able to stretch his arm from here to New York City. So, we are talking about extreme technical requirements in terms of the quality of the mirror and in the quality of the pointing system. These two aspects must interact to achieve the science requirements for this mission.

I would like to go back to the Lockheed portion of the chart to point out that we have completed a critical design review for the spacecraft; and, there were no surprises. I think that is a testament to the total project team in terms of how they have worked on this. It gives us some measure of confidence that, over the next year, we will have the ability—providing we have the good determination and project management that we have tried to apply in the last several years to live within our budget requirements.

For the planned activities, I again have color coded charts to show the consistency with the schedule. The colors on the left take us up close to where we are today. I have highlighted in the light blue what the fiscal year 1983 looks like. When we talk about the next year, I really am talking about this next period from where we are now through fiscal year 1983.

We will be doing the instrument assembly. You just saw the high speed photometer. The other instruments will be coming along for delivery into the system. We will be prepared to do the verification and acceptance testing at Goddard to see how these instruments interact with the computer system and how they interact with each other.

Again, we have had some difficulties with a detector tube on the faint object camera recently. We have to work around that; we expect that that camera will be coming into the system in time for us to deliver the total experiments to Lockheed. We also have some electronics equipment for that camera which will be arriving for testing at Goddard with the total system. Again, the controlled data handling is part of that, and it appears to be on track for the verification program.

If you look at the support system module, The period, which comes after the critical design review is manufacturing. That is a critical phase for us to get the components of the spacecraft properly manufactured. As with the instruments, there is an intense period of assembly and verification activities associated there.

We are in the integration and testing period of the optical telescope assembly which is a very critical item for us. Because, if you look at the fiscal year 1983 period, it is our peak funding year. We have requested $137.5 million for fiscal year 1983.

As far as future challenges go—chart 6—there are many that we are aware of, and I am sure you will be hearing about them from our associates. The key item here is the delivery of the optical telescope assembly. We believe that schedule is very tight. To deliver the assembly in time, it is going to take some good, tough management and progress from our associates, as well as our project team.

We have had some difficulty in developing latches for the science instruments. Most people would think that latches are pretty straightforward items to deal with, but it turns out that these latches—and there are some 50-odd of them that hold the science instruments and the fine guidance sensors in place—must be able to survive launch loads and they must hold these instruments very precisely in place in order for that dime to do what it does in New York City. These latches also have to conform to our thermal requirements. All of these aspects interact to make something that, on the surface, looks very simple, but actually is is a very difficult engineering challenge. Some latches are being delivered. We are in the process of working around this problem to get the remainder delivered and to minimize any further schedule impact.

I believe I mentioned the difficulty with the fine guidance sensors. Of course, we had to redesign that. That was part of our earlier problem in the spacecraft system. We will be getting those items in, but, again, there is a tight situation on the schedule.

With regard to contamination control, that beautiful mirror that I showed you has tremendous ultraviolet performance capability. It is better than we had anticipated, and that has made us more conscious about contamination. The materials used in the manufacturing of the spacecraft involves machining tools that have oil on them; therefore, we try to keep things very clean. However, it turns out that, in a space environment, unless we take great care in baking out this material in the total spacecraft system, this oil will outgas and deposit itself on the mirror. It is very much like the kind of thing we do to keep from getting a sunburn when we go to the beach. We put oil on our body to keep the ultraviolet rays from burning us. The rays are absorbed in the oil rather than reflected or absorbed by our skin. Consequently, we have a similar problem here, we would like to get a sunburn on the mirror, not the other way around. We are very conscious of this, and we may have to allow some time in the schedule to take care of that problem.

The alinement and total system testing is at where I would like to call your attention to in 1984, because all of these pieces are coming together. We are going to have the same problems that everybody has when they get into final integration and testing. We will probably have some difficulties that show up then.

The launch readiness schedule that you see on this chart is very near to the January timeframe. That is what our contractors are working toward. We have a commitment to Congress to get this thing launched in the first half of 1985, and that is the schedule that we are working toward.

In terms of the cost estimate, we have projected $725 million to $775 million in fiscal year 1983 budget dollars for the development program. I mentioned that our requirement of $137.5 million in 1983 is to get us through this very critical phase of the program.

As part of the 1982 budget We did request a $2 million reprograming from the mission operations part of the Space Telescope budget into the development phase to allow enough reserve through the 1982 period to insure that we did not inadvertently impact schedule any further than we absolutely have to. Those resources will be applied primarily to the optical telescope assembly that I identified as being a critical item on the schedule.

That completes my comments at this point. If there are any questions, I will be happy to answer them.

[The prepared statement of Dr. Martin follows:]

HOLD FOR RELEASE
UNTIL PRESENTED
BY WITNESS
MAY 25, 1982

Statement of

Dr. Franklin D. Martin
Director, Astrophysics Division
Office of Space Science and Applications

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

Subcommittee on Space Science and Applications
Committee on Science and Technology
House of Representatives

Mr. Chairman and Members of the Subcommittee:

It is a pleasure to appear today to provide an overview of the status of the development efforts of the Space Telescope Program. This statement includes a summary of major accomplishments, plans for the next year, major challenges, and an assessment of schedule and funding requirements. Since the Space Telescope Project Manager, Dr. Fred Speer of Marshall Space Flight Center (MSFC), provided the Chairman with a detailed discussion of project status in February, and since the associate contractors (Perkin-Elmer Corp. and Lockheed Missiles and Space Co.) will also be testifying today, I will keep my comments brief.

Prior to going into a review of the recent accomplishments, I would like to call your attention to the Space Telescope project responsibilities (Chart #1). In addition to the activities of the associate contractors, I will summarize the status of the Scientific Instruments which are managed through the Goddard Space Flight Center (GSFC). Also, you are aware that the European Space Agency (ESA), in addition to providing some support for the Space Telescope Science Institute, is contributing the Solar Arrays and the Faint Object Camera for the Space Telescope.

MAJOR ACCOMPLISHMENTS

Five Scientific Instruments will be flown in the Space Telescope: two cameras, two spectrographs, and a photometer. Although the principal function of the Fine

Guidance Sensors is to acquire guide stars and help to maintain pointing stability, they can be considered as a sixth scientific instrument when used in the astrometry mode. The assembly of the High Speed Photometer, the least complex of the Scientific Instruments, has been completed (Chart #2). The unit will be shipped from the University of Wisconsin, where it is being built, to GSFC for environmental testing following alignment of the optical elements. Fabrication and assembly of all other Scientific Instruments is in progress.

Except for the Faint Object Camera (FOC), all optical benches, optical elements, and detectors have been fabricated for the Scientific Instruments. The detector tube for the FOC had a design flaw which resulted in a crack in the glass enclosure. Two new flight tubes are expected to be delivered to ESA this July.

A very significant milestone was achieved by the successful completion of the polishing and coating of both the 94-inch primary mirror (Chart #3) and the smaller 12-inch secondary mirror by Perkin-Elmer. The resulting performance should meet our original goal of a total optical system wave front error of less than 1/20 of a wave. In addition, the polishing of the backup primary mirror has been completed by Eastman Kodak, and the mirror shipped to Perkin-Elmer for storage. The main ring and the metering truss, two structural units of the Optical Telescope Assembly (OTA), have been fabricated and their fit and alignment verified (Chart #4).

The Critical Design Review of the Support Systems Module (SSM), which is to be built by Lockheed, was completed in March 1982, and the design was declared ready for manufacturing. Internal shrouds are being added to the rate gyros in an attempt to reduce mechanical noise which would affect the stability of the Space Telescope. The results of noise characterization tests of these gyros showed a reduction of 100 in low-frequency noise. Fabrication of these gyros is underway to help insure that the required pointing stability performance will be met. Fabrication of the engineering model Data Management Unit has been completed; the multiple access transponders have been delivered; and the first flight computer was accepted.

PLANNED MAJOR ACTIVITIES - 1982

Planned activities (Chart #5) for the next 12 months will result in peak funding requirements for the Space Telescope Program.

Testing and calibration of the High Speed Photometer will be completed. The Support Electronics Box Assembly of the Faint Object Camera will be delivered to GSFC for completion of software. The assembly of all Scientific Instruments will be completed, and verification testing will begin at GSFC in March 1983.

Fabrication and testing of the latches which connect the Scientific Instruments to the Focal Plane Structure will be completed. Manufacturing of components for the OTA and the Fine Guidance Sensor will be continued, and integration and testing of the OTA will be started in December 1982.

Subcontract deliveries of most SSM systems will be completed. Manufacturing of SSM components at Lockheed will continue, including the fabrication of the flight Data Management Unit. Assembly of the Support Systems Module will be started in March 1983.

We are presently reviewing and developing the criteria and procedures for the development and execution of Maintenance and Refurbishment activities. Following this, we intend to initiate, at the beginning of FY 1983, action for the procurement of orbital replacement units. Design requirements for the necessary Space Support Equipment to perform in-orbit maintenance will be determined. In-orbit maintenance development testing will be continued in the Neutral Buoyancy Simulator at MSFC.

FUTURE CHALLENGES

Significant progress has been made in the development of the major optical components for the telescope and advanced detectors for the Scientific Instruments. We are all aware of the tremendous advancement in technology represented by the Space Telescope and the national and scientific importance of the successful completion of the ongoing development effort. As you know, we have had a tougher job than we anticipated. We have incurred cost growths in the Program, and we have been forced to extend the scheduled launch to the first half of 1985.

Hopefully, the bulk of our problems are behind us. However, there are still challenges ahead (Chart #6). Perhaps the greatest remaining technical challenge is the development of a pointing and control system that will achieve the pointing accuracy and stability necessary to complement the outstanding performance expected from the optical system. Based on science inputs, the present Space Telescope stability requirement is 0.012 seconds of arc for 24 hours; the Project goal remains at 0.007 seconds of arc. Prime factors for stability are the successful development of the rate gyros and the fine guidance sensors and insuring proper relationship between the Pointing and Control System, the Scientific Instruments, and the structural response of the Space Telescope.

The master schedule for the key elements of the Space Telescope Program is shown in Chart #7. The timely delivery of the OTA, along with the Fine Guidance Sensors, currently represents the tightest schedule area. The Focal Plane Structure, the Primary Mirror Assembly, and the Fine Guidance Sensors are critical-path schedule items. The graphite-epoxy Focal Plane Structure (Chart #8) was delivered to Perkin-Elmer last year. However, a structural strength problem of the flexures was discovered and subsequent testing has determined that a modification of the flexures is required. The situation is currently being studied.

The polishing and coating of the primary mirror took longer to complete than planned. Much work remains in assembling the mirror and the flight actuators in the main ring, and there is little slack in the schedule. The Fine Guidance Sensors are the most complex and challenging of any of the Space Telescope subsystems. One flight Fine Guidance Sensor, along with the OTA, is scheduled for delivery to Lockheed in December 1983. Phased delivery of the second and third flight units and the flight spare will follow in 1984. Again, little slack remains in this schedule.

Assembly of the Space Telescope will begin at Lockheed in January 1984 following checkout of the delivered OTA and the Scientific Instruments. Alignment verification and total systems testing makes this a very critical period for assuring the success of the Space Telescope. Any significant system failures during this time period would be especially difficult to correct and still maintain schedule.

BEST DOCUMENT AVAILABLE

Delivery of the latches, which are used to attach the Scientific Instruments to the OTA, is somewhat behind schedule. Vibration testing will be undertaken at MSFC later this summer to verify the alignment and safety of these latches.

The final challenge that I would like to briefly address is the problem of controlling contaminants from degrading either the optics of the Scientific Instruments or the optical telescope. The ultraviolet (UV) properties of optics are extremely sensitive to contamination, and control requirements that are more stringent and which exceed original contract specifications are being considered for implementation by the Project. It appears that these contamination control requirements may have to be adopted to help insure getting science data in the very important UV wavelengths.

BUDGET

The estimated runout cost for completing Space Telescope development is $725-775 million, in dollars of the FY 1983 budget. This estimate supports the planned Shuttle launch of the observatory in the first half of 1985. We believe the estimate is adequate to meet the remaining challenges which we have discussed; however, tight management controls must continue while observing the integrity of mission objectives.

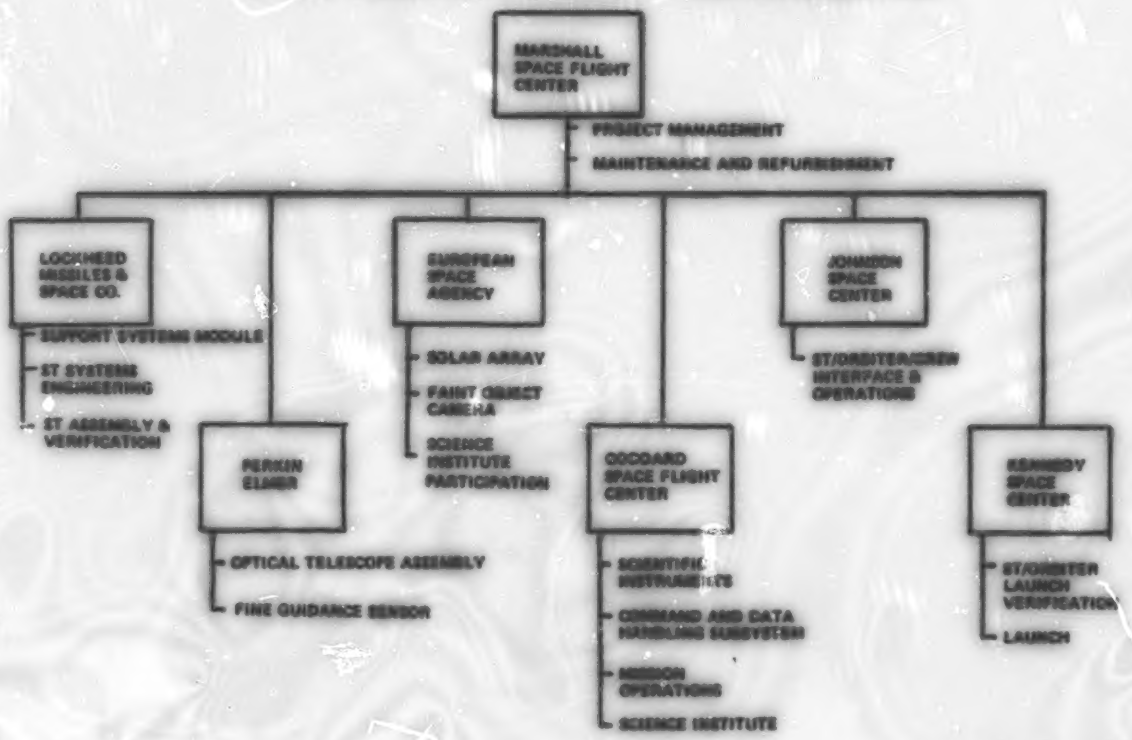
Of the total estimate, $468.7 million has been authorized through FY 1982. This includes a proposed $2.0 million reallocation in FY 1982 from "Space Telescope Operations" to "Space Telescope Development." This requested reallocation in the FY 1982 budget is needed to provide resources for schedule maintenance of the OTA during this critical phase of development activity.

The FY 1983 budget request for Space Telescope development is $137.5 million. This represents the peak funding for this program. This funding level is required to support the intense effort needed to complete the fabrication and assembly of most major subsystems, as well as to carry out verification testing of the Scientific Instruments.

Mr. Chairman and members of the Subcommittee, that concludes my testimony. I would be pleased to answer any questions from the Subcommittee.

Chart A

SPACE TELESCOPE PROJECT RESPONSIBILITIES



MARSHALL SPACE FLIGHT CENTER
- PROJECT MANAGEMENT
- MAINTENANCE AND REFURBISHMENT

LOCKHEED MISSILES & SPACE CO.
- SUPPORT SYSTEMS MODULE
- ST SYSTEMS ENGINEERING
- ST ASSEMBLY & VERIFICATION

PERKIN ELMER
- OPTICAL TELESCOPE ASSEMBLY
- FINE GUIDANCE SENSOR

EUROPEAN SPACE AGENCY
- SOLAR ARRAY
- FAINT OBJECT CAMERA
- SCIENCE INSTITUTE PARTICIPATION

GODDARD SPACE FLIGHT CENTER
- SCIENTIFIC INSTRUMENTS
- COMMAND AND DATA HANDLING SUBSYSTEM
- MISSION OPERATIONS
- SCIENCE INSTITUTE

JOHNSON SPACE CENTER
- ST/ORBITER/CREW INTERFACE & OPERATIONS

KENNEDY SPACE CENTER
- ST/ORBITER LAUNCH VERIFICATION
- LAUNCH

NASA HQ [illegible] (1)
[illegible]

CHART #1

SPACE TELESCOPE

PLANNED MAJOR ACTIVITIES - 1982

OPTICAL TELESCOPE ASSEMBLY (OTA)

- START INTEGRATION AND TEST OF OTA (DECEMBER 1982)
- TESTING AND FABRICATION OF SCIENTIFIC INSTRUMENT/OTA LATCHES WILL CONTINUE
- CONTINUE MANUFACTURING OF COMPONENTS

SCIENTIFIC INSTRUMENTS

- COMPLETE ASSEMBLY OF ALL INSTRUMENTS IN PREPARATION OF VERIFICATION TESTING
- TEST AND CALIBRATE HIGH SPEED PHOTOMETER
- SUPPORT ELECTRONICS BAY ASSEMBLY OF THE FAINT OBJECT CAMERA DELIVERED TO GSFC FOR SOFTWARE DEVELOPMENT

SUPPORT SYSTEMS MODULE

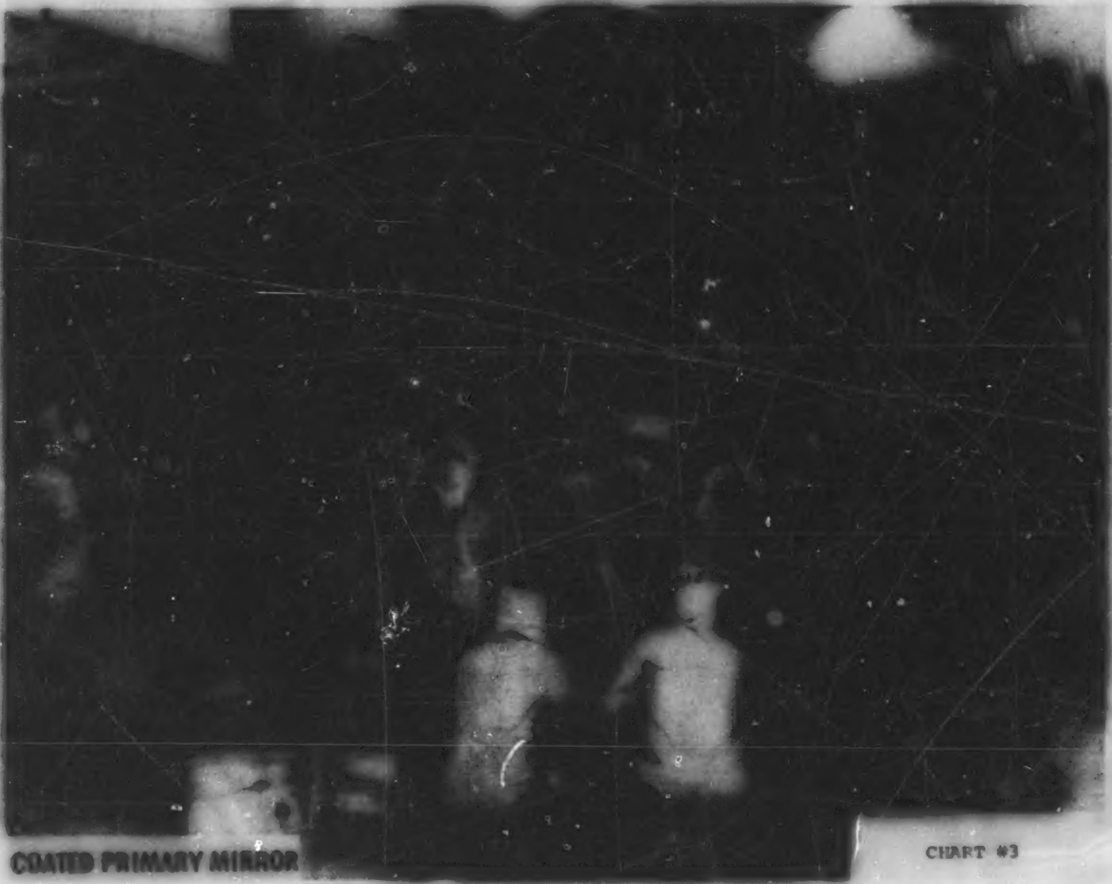
- COMPLETE TESTING OF DATA MANAGEMENT UNIT ENGINEERING MODEL, START FABRICATION OF FLIGHT UNIT
- CONTINUE MANUFACTURING OF COMPONENTS
- START ASSEMBLY OF SUPPORT SYSTEMS MODULE (MARCH 1983)

CHART #5

BEST DOCUMENT AVAILABLE

SCIENTIFIC INSTRUMENT HIGH SPEED PHOTOMETER CHART #2

BEST DOCUMENT AVAILABLE

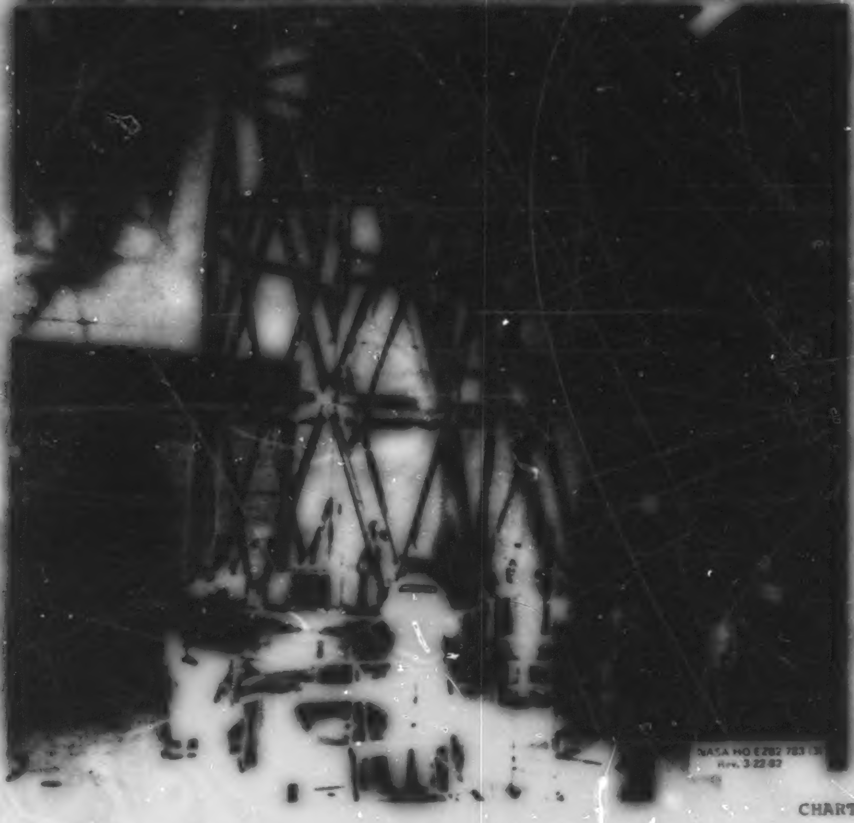


COATED PRIMARY MIRROR

CHART #3

59

SPACE TELESCOPE METERING TRUSS AND MAIN RING



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Rev. 3-22-82

CHART #4

SPACE TELESCOPE

FUTURE CHALLENGES

- O TIMELY DELIVERY OF OPTICAL TELESCOPE ASSEMBLY
  - FOCAL PLANE STRUCTURE
  - PRIMARY MIRROR ASSEMBLY
  - FINE GUIDANCE SENSORS
- O SCIENTIFIC INSTRUMENTS LATCHES
- O CONTAMINATION CONTROL
- O POINTING AND CONTROL SYSTEM PERFORMANCE
- O ALIGNMENT AND TOTAL SYSTEMS TESTING

CHART #6

BEST DOCUMENT AVAILABLE

SPACE TELESCOPE PROJECT MASTER SCHEDULE

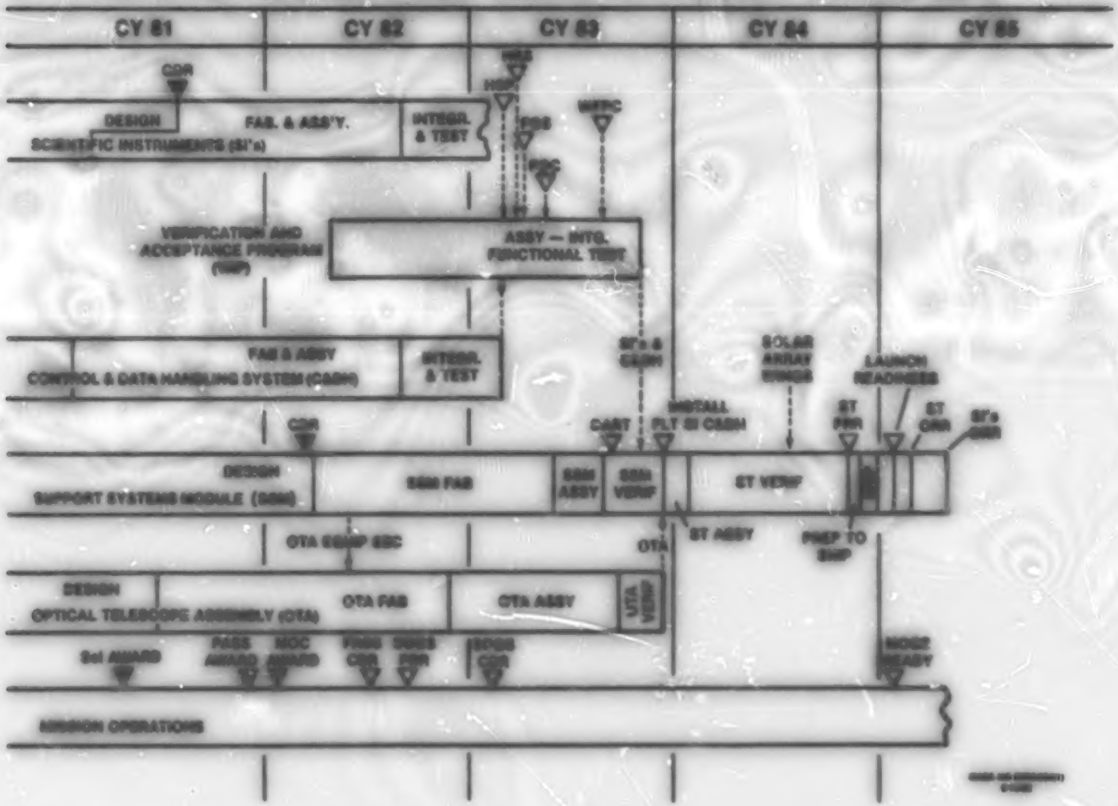

CHART #7

63

FLIGHT FOCAL PLANE STRUCTURE

CHART #6

Mr. **Flippo**. I did have a question about the critical design reviews. We had heard that NASA did not propose to have these hearings, that the contractors proposed them. Would you comment on that?

Dr. **Martin**. The hearings?

Mr. **Flippo**. The critical design reviews for the main component systems.

Dr. **Martin**. To my knowledge, the critical design reviews have always been a part of our contracts. We could go back and provide those, if you like, but I don't think it is necessary.

Mr. **Flippo**. No. That is fine.

Mr. Brown, do you have any questions at this point?

Mr. **Brown**. This is going to be launched on the Shuttle; is that correct?

Dr. **Martin**. Yes, sir.

Mr. **Brown**. Could you help me to understand a little bit the degree to which the scheduling may have been impacted by the changes in the Shuttle launch scheduling?

Dr. **Martin**. Of course, the Shuttle is up and flying now. It is scheduled to be operational after STS-4. We are manifested on the Shuttle for a flight in the first half of 1985. Other than the problems associated with delay in getting more detailed information on the launch loads and Shuttle environments and things of this sort, I don't know of anything that has directly contributed to the problems that we had to deal with. It is always nice to know what those launch loads are when you are in the earlier phases of your design activity, but I don't believe any of those things contributed in a major way to the cost growth of the program.

Mr. **Brown**. The Shuttle launch schedule has slipped somewhat over the past several years. I am trying to identify whether you were always scheduled to launch on Shuttle No. X, or whatever it was. Did Shuttle No. X launch schedule lag to some degree, and has this impacted your target dates as you went along, or has your slippage been entirely independent of whatever happened to the Shuttle?

Dr. **Martin**. Sir, we did it to ourselves in that sense. Our original plan was for a December 1983 launch. Because of our technical problems and schedule problems, we sliped to the first half of 1985.

Mr. **Brown**. But would a Shuttle been available for launch at that 1983 date, regardless of your situation?

Dr. **Martin**. I don't see why not. I think the one caveat I would put on that—and I really haven't had a chance to think about it—I spoke yesterday of the direct ascent that we planned to use, and I certainly would like Orbiter 099 for that ride.

Mr. **Brown**. Just a matter of orientation, can you help me to understand the major differences between this project and something that we have dealt with frequently, such as the Landsat project that the proposed new instruments that we are putting on that, the thematic mapper, and so forth? What are the similarities and differences in the technical problems?

Dr. **Martin**. I will have to plead a little ignorance in the sense because I am not directly involved with the Landsat program. I can comment, though, that the Space Telescope is technically one of the most challenging projects that we have been associated with in the astronomy area because of the pointing requirements and the stability requirements. I think that drives the system, as I mentioned earlier.

I think, also, something that has been a real challenge for us is the fact that we are building a system that, unlike the multimission spacecraft that has modules that you can take in and out and are located externally—we are actually taking major components out of the spacecraft and replacing them. That situation has been quite a technical challenge in terms of insuring that things are properly alined when you remove them and put them back. I don't believe those kinds of items are a part of the Landsat program, and they certainly have not been a part of the other programs I have been associated with.

Mr. **Brown**. I am wrestling with the problem of asking you to make comparisons with the classified programs in this area, but I guess I don't know enough to phrase that question properly. I had better skip it.

I will defer any further questions, Mr. Chairman.

Mr. **Flippo**. We are familiar somewhat with the AXAF program. Will the things we have learned on the Space Telescope program help us to reduce the cost on AXAF, or is that a totally different approach?

Dr. **Martin**. There are several things about the AXAF program. No. 1 is that the X-ray pointing requirements are less stringent than the UV optical pointing requirements are for the Space Telescope. So, the system should be much simpler to do in terms of the requirements.

We have learned a great deal about maintenance and refurbishment through the Space Telescope program which are directly applicable to the AXAF system. The AXAF is a telescope on the same scale and size as the Space Telescope, and certainly lends itself, through a competitive environment, of course, to using some of the same subsystems as far as spacecraft components. So, there is a lot of synergism there.

I think we have learned a great deal. In fact, we have our own internal study going on in looking at maintenance and refurbishment in particular for the AXAF, given the lessons learned from previous missions. That report should be completed later this year.

Mr. **Flippo**. One of our biggest problems is that this committee authorized the Space Telescope in 1978, as your chart points out—the funding years from 1978—starting out with somewhere between $435 million and $470 million estimated cost and then going to its current cost today.

We thought that the technology was pretty well in hand, although we just really didn't understand the degree of the challenge that we faced; is that correct?

Dr. **Martin**. I think that is correct on all fronts, as I mentioned, in all three segments of the program, including the spacecraft segment, which my associates from Lockheed can certainly speak to. There is a big difference between building something that will fly in the normal sense and expend itself in space, and building something that you are going to maintain and refurbish on orbit. That is proving to be a new challenge to us.

As far as the budget requirements go—I know I am reminding the chairman when I say this—but when we started the project in fiscal year 1978, there was a decision made that for this project, as in the case of the Space Shuttle, that we would budget in budget year dollars. Consequently, as you come up through the 1981 budget, there is an increase in the budget purely because we were budgeting in budget year dollars, not because we had any problems. So there really was no growth in the program until we came upon our problems in 1980 that led to the adjustment in the President's 1982 budget.

I would like to comment on that, if I could. If you took that 1982 budget and compared it with our original program, that budget range would have been $535 million to $591 million. Instead, we came to you requesting a range of $700 million to $750 million. The difference there is approximately $160 million, and $40 million of that is directly attributable to the fact that we had to project inflation rates at least 18 months ahead of the time that they are encountered. We, very frankly, underestimated the inflation rate, as a lot of other people have in the government in recent years. The rest of that amount, about $120 million, was due to a combination of technical and schedule problems. I would estimate about 40 percent of that was technical, the other 60 percent was because we had to slip the schedule approximately 1 year.

Mr. FLIPPO. In regard to the mirror, you used the phrase "diffraction limited,"—that the mirror is being characterized as diffraction limited. What does that mean?

Dr. MARTIN. In very simple terms, it has to do with the wave fronts as a function of the diameter of the mirror. But I think the best thing to think about is, if we made it any better, it wouldn't make any difference. If it were any smoother, we could not do any better. It would do us no good to continue to polish and refine it beyond that.

Mr. FLIPPO. Do you have any plans for the backup mirror?

Dr. MARTIN. Right now, the backup mirror is also a fine mirror. We will keep that mirror in bonded storage to protect it. We would like to get through the first flight, of course, the launch and the operations for the telescope. Of course, if we bring it back down to the ground, I would like to make sure there is no crack in the one we got. It is very important to us. It is conceivable that, sometime in the future, we might even loan the spare to someone to use in a safe environment. But, I don't anticipate us doing anything but taking great care of that mirror until after we have gone through our first ground refurbishment.

Mr. FLIPPO. Thank you very much for your testimony.

We see the presence of the full committee chairman, the distinguished gentleman from Florida, Mr. Fuqua. Would the gentleman from Florida have any questions?

Mr. FUQUA. No, Mr. Chairman, I don't have any questions. I am just getting the latest update on the telescope.

Mr. FLIPPO. I suppose we better go into recess to vote, and then come back. It looks like it is going to be that kind of day.

Dr. MARTIN. We will be patient. Thank you.

[Recess.]

Mr. FLIPPO. The subcommittee will come to order.

Thank you, Dr. Martin, for your testimony.

With our next witnesses, perhaps we would best conserve time by asking all of the gentlemen to come to the table as a panel, if that is acceptable.

We have Mr. Ed Ronan, senior vice president and general manager of the optical group of the Perkin-Elmer Corp., and you might introduce the gentleman accompanying you. We are pleased to have Dr. Oder, vice president and general manager of the space systems division of Lockheed Missile and Space Co.; and Mr. William Wright, vice president for NASA programs at Lockheed.

We will, of course, accept your entire statements for the record. Please feel free to present your testimony as you see fit.

STATEMENTS OF EDWARD F. RONAN, SENIOR VICE PRESIDENT, GENERAL MANAGER, OPTICAL GROUP, PERKIN-ELMER CORP.; JOHN D. REHNBERG, GENERAL MANAGER, OPTICAL TECHNOLOGY DIVISION, PERKIN-ELMER CORP.; DR. FREDERIC C. E. ODER, VICE PRESIDENT AND GENERAL MANAGER, SPACE SYSTEM DIVISION, LOCKHEED MISSILE AND SPACE CO.; WILLIAM WRIGHT, VICE PRESIDENT, NASA PROGRAMS, LOCKHEED MISSILE AND SPACE CO., ACCOMPANIED BY BERTRAM R. BULKIN, SPACE TELESCOPE PROGRAM MANAGER, LOCKHEED MISSILE AND SPACE CO.

Mr. Ronan. Good morning. My name is Ed Ronan. I am the senior vice president and general manager of Perkin-Elmer optical group. I would like to thank you for this opportunity to appear before the subcommittee this morning.

Actually, this is the second time that we have had the opportunity to appear. We first testified in July of 1978, during the earlier stages of the program. In addition to that, we have been pleased to host some staff members of the committee in our plant at Danbury in January of 1980.

Since that time, we have made significant progress on the program. We now have in hand a substantial amount of flight hardware and we feel that this will enable us to deliver the OTA on schedule and within cost. We feel that we are going to have a state-of-the-art instrument, one of the finest that has ever flown.

Perkin-Elmer is committed to work with NASA and Lockheed. We have a very fine working relationship with both organizations. We intend to work with them and continue to balance our technical risks with emphasis on minimizing the cost of the program.

Our presentation today will be made by Mr. John D. Rehnberg. Mr. Rehnberg is a vice president of the Perkin-Elmer Corp., and is the general manager of our optical technical division where the OTA portion of the telescope is being designed and built. During the course of his presentation, Mr. Rehnberg will talk about our accomplishments to date on the program. He will talk about some of the challenges that we have had and how we have overcome them. He is going to talk with special emphasis on the Primary Mirror, and in particular about the national resource that we have developed during the course of the program. We are very proud of it. We think it is one of the finest optical fabrication resources in the free world today. Lastly, Mr. Rehnberg will discuss the challenges that we perceive ahead of us and how we intend to deal with them.

I would like to now introduce Jack Rehnberg.

Mr. Rehnberg. Mr. Chairman and members of the subcommittee, it is a pleasure to appear here today.

We at Perkin-Elmer are responsible for the optical telescope assembly portion of the Space Telescope. In this capacity we are responsible for the designing, building, and qualification of all optical telescope subsystems which include the optics, the structures, the fine guidance sensors, the optical control subsystems, as well as the electronics associated with these subsystems.

The assembly of the OTA and performance verification will take place at Perkin-Elmer. We will then verify interfaces with the science instruments and perform the integration of the science instruments into the OTA. We will also support Lockheed in the interfacing of the OTA with the support systems module.

The focal plane integration will take place at Perkin-Elmer, and then the assembly will be shipped to Lockheed Missiles and Spacecraft Corp. for ultimate integration and preparation for launch.

Next chart, please.

I would like to just take you through a simplistic buildup of the optical telescope assembly shown on your left. We see a number of the major subassemblies of the OTA in breakout form. As we start assembling the OTA, the primary mirror will be integrated to the main ring, which I will show you some real photographs of later on.

This is a very critical assembly process and must be done with a minimum amount of distortion to the primary mirror.

Next chart, please.

Next we bring to the main ring assembly some baffles which are used to prevent the stray light from space, Earth, Sun, and Moon from entering the telescope assembly.

Next chart.

We then integrate a graphite epoxy truss structure. This truss structure weighs 250 pounds and is a very novel new material that allows us to provide the temporal and dimensional stability of the spacing between the primary mirror and the secondary mirror which is critical for the optical telescope assembly performance. It will allow maintenance of long-time exposures, for periods of up to 24 or more hours, under thermal conditions which will permit changes in temperature of the structure of as much as 280 degrees Fahrenheit without distorting the performance of the assembly.

After that assembly is brought together, we integrate the flight focal plane deck here for the science instruments. It is also a graphite epoxy structure.

Then it is followed by the integration of some instruments. These instruments are the fine guidance sensors and also the optical control subsystem, which are used for providing the necessary control monitoring of the optical telescope assembly.

Next chart, please.

I would like to briefly go back and revisit 1978. At that point in time, we statused the program by the major subsystems and gave you an assessment as to where we were at that point in time.

At the present time, you can see a number of these assemblies are complete. I will show you pictures of the hardware in the completed form getting ready for assembly. The primary and secondary mirrors are complete. The metering truss structure was delivered from Boeing about a year and a half ago. The focal plane structure is complete.

We do have some rework problems on one of the structures that I will show you. We can discuss that. The main ring is in-house and complete and being prepared for integration. And the baffles are near completion.

The main sensor subsystem, the fine guidance sensor, the optical control subsystems, and the OTA electronics are in the final fabrication stages at this point in time.

I would like now to discuss the primary mirror, which is the critical heart of the optical telescope assembly. It is a 2.4 meter diameter diffraction limited mirror. What this means is we can collect every bit of energy that is the ultimate for resolution of this diameter.

To our knowledge, it is the largest and best quality of its size in the free world. The reflectivity shown there is measured in the ultraviolet. It exceeds the original design performance by about 10 percent. I will show you some pictures of the unique coating chamber that was developed for the coating of that mirror.

Next chart, please.

I shall now go through quickly some pictures that show the buildup and the fabrication cycle of the primary mirror.

The first thing that we do with the mirror when it comes to us from Corning is to do the necessary shaping and grinding of it. It comes in rather rough form, and the edging, back and front surfaces of the mirror must be shaped and ground to a very precise radius so we can have referencing.

This process takes about 6 months for all of the preparatory work.

We then put a very quick shine on the mirror in preparation for the final polishing. Here we have some of our opticians actually undergoing inspection of the fine core. You can see the latticework here. It is a lightweight glass mirror structure with about 70 percent of the glass removed. So it weighs 1,800 pounds, but in the normal solid state it would be three times as heavy as that if we had to work with the solid.

The next chart, please.

We then bring the mirror into a computer controlled polishing facility. This is the first time a mirror has been totally finished using numerically controlled methods.

In order to do this operation, we had to devise a number of support facilities. The aluminum structure you see here has several hundred little point actuators under the mirror. Those are used to make the mirror appear that it is floating in space. We actually have a neutral buoyancy predetermined so that the mirror is counterforced to provide the necessary free space environment that the mirror will see when it is attached to the telescope in orbit. If we had polished under a 1-G environment, the mass properties of the mirror would be such that we would polish in and have a deformed mirror, and when we flew it, we would have strain built into the mirror which would cause some deformation. So we have factored all those things into an analysis and predicted those effects in advance and run a number of iterative tests back and forth to assure that the process was well under control.

The next sequence of pictures shows the manner in which we capture the surface of the mirror. The squiggly lines we see here is what we call an interferogram. It is really a photograph of the mirror taken with laser light through an instrument called an interferometer. It is a very special kind of interferometer, and it allows us to map the surface of the mirror which is precisely determined from the mathematical design of the telescope.

These squiggles here, the maximum ones, show the local mapping variation. At this stage of fabrication, the mirror was out of tolerance by about 100 times from an acceptable surface. The surface errors, instead of being a millionth of an inch across, were about 100 millionths of an inch across, as Dr. Martin indicated before.

We then take hundreds of these kinds of interferograms, computer process them, and generate a contour map. It is a synthetic surface map made from hundreds of these interferograms, and it averages out lots of confusing effects from atmosphere and things like that. We use this data to determine the highs and the lows of the mirror very accurately.

That data then is processed back into the computer and commands the machine to do the necessary processing on the mirror in the precise manner. After about 20 or 30 processes, these squiggles become very straight lines. The straightness of those lines, the spacing of each line, is about a half of a wave each. Then we measure the uniformity of those straight lines, generate some more interferograms, and come up with a mapping situation here which is almost totally white, and that tells us that we are finished. At that point in time, we have a mirror that is better than the required one sixty-fifth wavelength average error.

This is the Primary Mirror and its support structure as we were cleaning and preparing it for coating. Once we finish the fabrication of the mirror, we must then put on a very precise coating which will enhance the ultraviolet.

For this operation, it sounds like you just put a flash of aluminum on it so you can reflect. But it is very critical. We found out earlier on the orbiting astronomical observatory program, as well as on other ultraviolet programs, that, in order to get the necessary enhancement in the ultraviolet, you have to put on the coatings very fast with very, very hard vacuums, and under very precise controls.

In order to do that, we had to develop this chamber facility under the Space Telescope program. It is really a unique facility. It took three years in the design preparation and installation of this facility—which is capable of depositing a coating in 80 seconds. I must point out that it was a remarkable support effort from the NASA people as well. The people at Goddard Space Flight Center were very helpful in the early stages of the development of this coating work.

But all of the coating preparation work, the analysis, the prediction of the evaporators and how that had to occur had to be sequenced and checked beforehand. We did not want to have to run the risk of removing the coating and than having to try again because it would have some deteriorating effects on the mirror.

This is the mirror in the final finished form. I must say that the reflectivity achieved was about 10 percent higher in reflectivity than the specification. So we are giving the science community about 10 percent more photons than they originally planned to get from both the primary and the secondary.

Again, another picture of the coated mirror shown earlier by Dr. Martin.

This is a photograph of the secondary mirror. Although it is smaller, 16 inches in diameter, it is also a very difficult element to build, because the optics associated with building it and testing it have to be unique, it has to be mapped very accurately across its surface, and it is just as difficult and critical as the primary mirror in determining the final ultimate performance of the Telescope.

I don't have a picture of the coated secondary, but I can tell the committee at this point that it is complete, and we do have it in bonded storage and ready for integration into the Telescope assembly.

I would like proceed into some of the photographs of the flight structures as they are currently being prepared for integration at Perkin-Elmer.

This is the main ring. It is a titanium ring. It really is the backbone of the Optical Telescope assembly. As I showed earlier, the primary mirror mounts in here, and the other subassemblies mount to the main ring, and it becomes the main integrating structure for the support systems module that Lockheed supplies.

This shows a fit check between the truss structure, which is graphite epoxy with the main ring.

To the back of the main ring goes the deck on which the science instruments mount. This is graphite epoxy. It was manufactured for us by Boeing in Seattle. You have heard some commentary about some flexure problems. These flexures here, these V-shaped devices, undergo some severe loads during launch. We are having some difficulties right around the joint right there. We do have some engineering solutions to that problem, and we feel confident that we will be able to solve the problem.

This, again, is a photograph of one of the subsystems for the fine guidance sensor under assembly. Again, we used graphite epoxy on the optical bench structure because of its properties of low thermal coefficient of expansion necessary to hold the precision optical tolerances for very long periods of time necessary for the Space Telescope.

I would like to now just highlight some of the major milestones and the future challenges for the optical telescope assembly. We see here in ascending order some of the major assemblies as they go together with the respective time lines and when we expect to complete those assemblies. We are in the process of initiating some of that work right now and, in the next 12 to 18 months, we will be actively engaged on all of these items.

We see some challenges ahead in the primary mirror assembly because we do not want to disturb the excellent figure quality that we have in the mirror at the present time. All the assembly and integration of it to the other structures must be done in a manner so that we don't perturb the excellent performance that we currently have.

On the focal plane assembly, as I indicated, we do have some problems on the flexures that we are working on, and we are confident that we will be able to solve those problems successfully.

In the fine guidance system, we don't anticipate any major difficulties at this point in time. Our major concern is that we do not have an engineering model or qualification model of the total subsystem and will not have that kind of information available until we validate flight hardware a year from now as we start building up the first flight unit. We have had excellent simulations, jointly with Lockheed, in predicting the performance of the pointing control subsystem and the fine guidance system, and we are confident that we will be able to proceed ahead successfully into the next phase.

Alinement and integration in test are naturally challenges that we will have to face and, as Dr. Martin has indicated, contamination control is always a problem with ultraviolet instruments.

Next chart, please.

The chart on your right shows the funding requirements running out through the launch of the ST. This is actual, and this is the projected spending for the remainder of the program. As you can see here, the critical design review for the optical telescope assembly was completed almost 2 years ago, and we are well on our way into the fabrication process on the program.

In summary, I believe that the program has successfully transitioned into the hardware integration stage. The fine guidance system development is challenging, but we think we are on top of it, and we think we will be successful with it. We have very high confidence in our ability to progress through to delivery in December of 1983. Although the schedule is tight, we believe it is achievable.

I would like to thank the subcommittee for the opportunity to appear before you today.

[The prepared statement of Mr. Rehnberg, plus charts mentioned in his oral presentation, follow:]

Statement of

Mr. John D. Rehnberg
Vice President, General Manager
Optical Technology Division
THE PERKIN-ELMER CORPORATION

before the

Subcommittee on Space Science and Applications
Committee on Science and Technology
House of Representatives

Mr. Chairman and Members of the Subcommittee:

I would like to start with Perkin-Elmer's role in the Space Telescope Program. The first figure provides an overview of our contract scope. We will design, build and qualify all Optical Telescope Assembly (OTA) subsystems which includes optics, structures, Fine Guidance Sensors, Optical Control Sensors and OTA Electronics. We will assemble the OTA and conduct tests to verify its technical performance. An important part of our job is to pay special attention to interfaces with the Support Systems Module and Scientific Instruments. We will insert the Scientific Instruments into the Focal Plane Structure and after OTA delivery to Lockheed, we will support the Space Telescope integration and launch.

The next few figures illustrate the hardware build-up to the OTA. I would like to point out the major components of the Optical Telescope Assembly and how they are combined to make up the final assembly. Later in the

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presentation we will view actual hardware. The Primary Mirror mounts to the Main Ring which is the structural backbone of the telescope. Then three (3) baffles (Main, Central and Secondary) are added to control stray light. Next, the Primary and Secondary mirrors are aligned and spaced by the Metering Truss Structure. The Focal Plane Structure, a platform for mounting the Scientific Instruments, is added to the other side of the Main Ring. Fine Guidance Sensors and Optical Control Sensors are then installed, completing the OTA.

The next two figures show a comparison, by major hardware element, between the status in 1978 (our previous presentation to this subcommittee) and the status today. Let's follow today's status. Both the Primary Mirror and the Secondary Mirror blanks were manufactured for us by Corning. The Primary Mirror has been completed through polishing, coating and post-coat testing. The mirror exceeds specifications in both figure and reflectivity. The Backup Primary Mirror has been polished and is a very good backup should it be required. The possibility that it will be needed is remote. The polishing, coating and post-coat testing of the Secondary Mirror has been completed and this mirror, like the Primary Mirror, meets or exceeds specifications in every respect.

The Metering Truss Structure and the Focal Plane Structure were manufactured for us by Boeing. The Metering Truss Structure is completed and has undergone preliminary integration fits with the Main Ring. The function of the Metering Truss Structure is to control alignment and spacing of the Primary and Secondary mirrors. It is fabricated from graphite epoxy, a relatively new material whose characteristic of a low coefficient of thermal expansion enables the structure to hold these critical optics in precise alignment despite temperature changes in space of more than 280°F. Graphite epoxy also has the combined advantage of low weight and high strength. The

Focal Plane Structure, also constructed of graphite epoxy, is complete through fabrication. Post-fabrication testing of some graphite-epoxy test samples has led to the conclusion that a marginal strength situation exists with the flexures. Several alternate approaches to modifying the flexures are currently under consideration and we expect to select an approach very soon.

The Main Ring is complete and we have started assembly of the final hardware. Two of the three required baffles are complete and the third (Main Baffle) is in the fabrication cycle. The latch program has proven to be more of a challenge than anticipated. The requirements placed on the latches are very demanding. The weight of a Scientific Instrument (approximately 700 pounds) must be supported in such a way as to maintain precise optical alignment under varying load conditions. Some design effort and fabrication remains. Fabrication and assembly of the Fine Guidance Sensor is also a complex task, since it is required to precisely align the telescope for periods of time up to 24 hours. We are in the fabrication stage and are giving this area special attention. OTA Electronics are also proceeding well along the fabrication stage.

The Subcommittee has expressed an interest in the development of the Primary Mirror. The next few figures will guide us through the mirror development process and will provide a look at the actual flight hardware elements which comprise the OTA.

As previously stated, the mirror is now coated, the final step in the fabrication process. The mirror represents approximately two years of effort at Perkin-Elmer. The completion of this task is a significant achievement. The computer-controlled polishing technique was proven on this large 2.4 meter (96-inch), 1,827-pound mirror. The end product is the most precise large optic in the world, better than its specification of 1/65 of a wave, with a reflectivity of 85%. A unique coating chamber was procured and special handling equipment developed to accommodate the mirror.

The mirror was ground to a sphere at Perkin-Elmer early in the fabrication process. Approximately 300 pounds was shaved from the mirror blank during grinding and subsequent polishing. Optical engineers verified the surface following grinding. A dedicated computer-controlled polishing facility was used in tandem with a mirror testing facility during the intensive polishing/testing process. In order to track the smoothness of the mirror surface pictures, or interferograms, of the mirror were taken in the testing facility after each polishing cycle. As the surface was smoothed, the lines on the interferogram became straightened. The color topographical map is another method of tracking the high and low points of the mirror, the color becoming whiter as a uniform surface is approached. When polishing was completed, the mirror was prepared for coating. Reflectivity and uniformity specifications of the coating required that a unique vacuum chamber be developed which had the physical dimensions and extremely low pressures required to meet these challenges. The coated mirror was taken from the chamber and placed in its support dolly for inspection.

The Secondary Mirror was polished, coated, and stored in anticipation of integration into the Secondary Mirror Assembly. The Main Ring is the structural backbone of the telescope to which both the Metering Truss Structure and Focal Plane Structure are joined. Fit and alignment checks have been made on the Metering Truss Structure/Main Ring Assembly. The "inverted V" shaped legs located at the base of the Focal Plane Structure are the flexures which require modification. There are four of these on the structure. Some of the critical components of the Fine Guidance System are shown inside one of our clean rooms as assembly started.

There are a number of remaining major milestones leading to OTA delivery which represent significant challenges from a schedule standpoint. These include completion of major assemblies, such as the Primary Mirror Assembly, Focal Plane Assembly and Fine Guidance System. These are key assemblies which must be assembled with precision. In addition, the Flight Focal Plane Structure Flexure modification must be accomplished with the least impact to the program. OTA alignment must be accomplished to very precise tolerances. OTA integration and test will be a most exciting, but challenging period when the major assemblies are joined. Finally, the risk of contamination to optics, large and small, must be addressed.

OTA funding requirements have been met by NASA. Our requirements are expected to peak in FY 1983 and fall off significantly in FY's 1984 and 1985.

SUMMARY

An overview of the OTA Program shows that we have successfully transitioned to the hardware integration stage. There are future challenges ahead such as the Fine Guidance System development. However, we do have high confidence in our ability to progress through delivery and provide a state-of-the-art instrument. The schedule for doing so is tight but it is achievable.

PERKIN-ELMER

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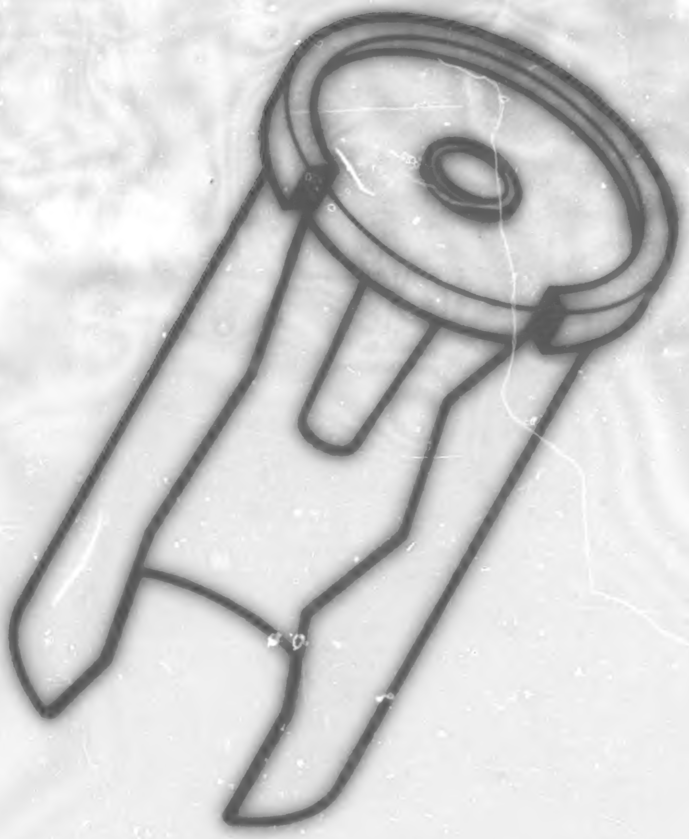
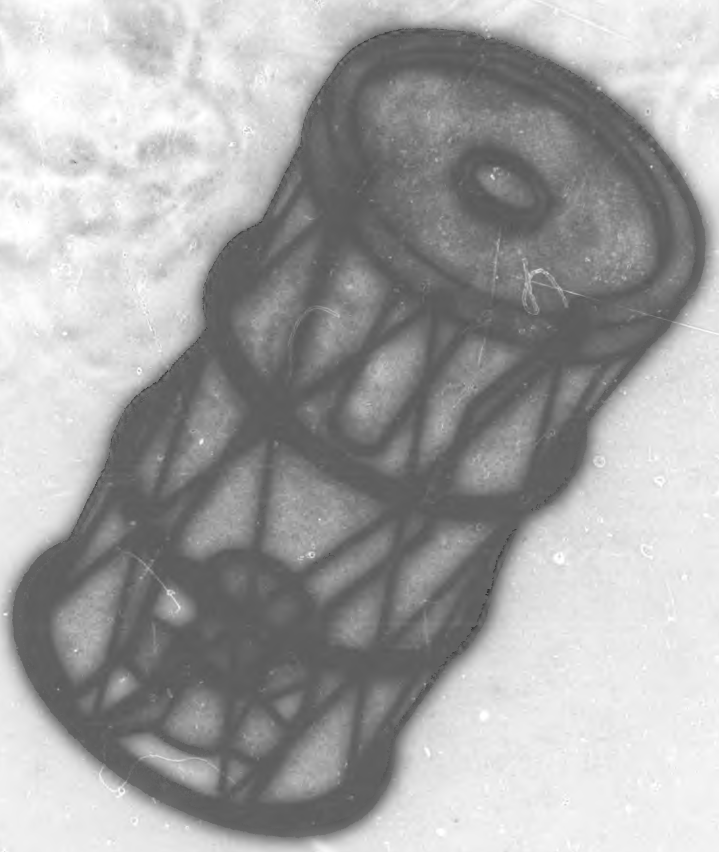
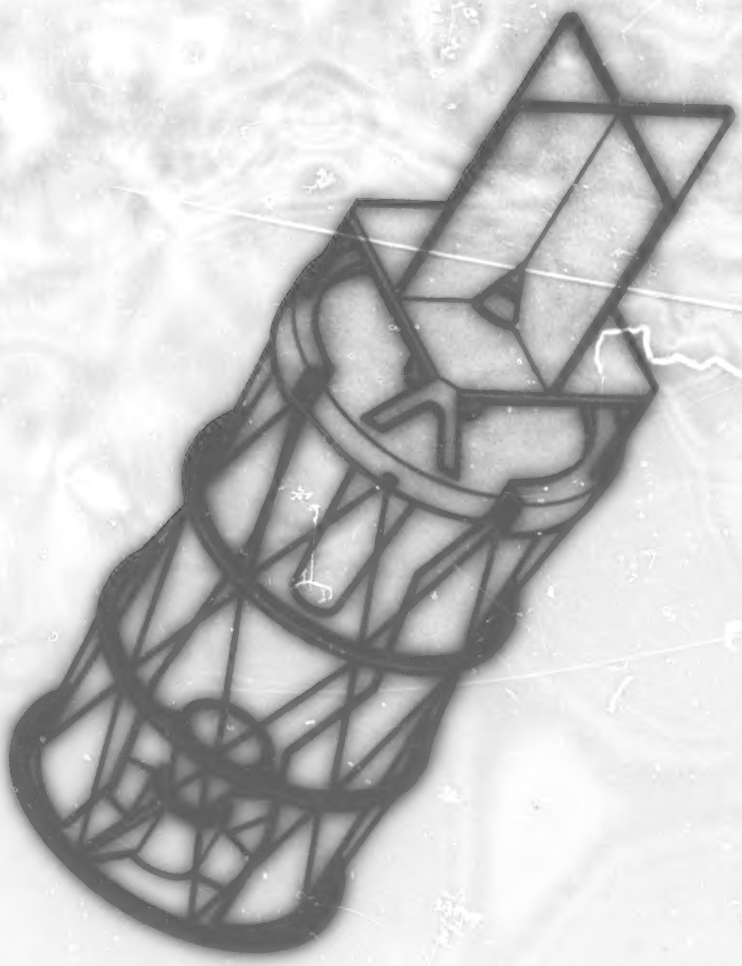
OPTICAL TELESCOPE ASSEMBLY PROGRAM
AT PERKIN-ELMER
CONTRACT NAS8-32700

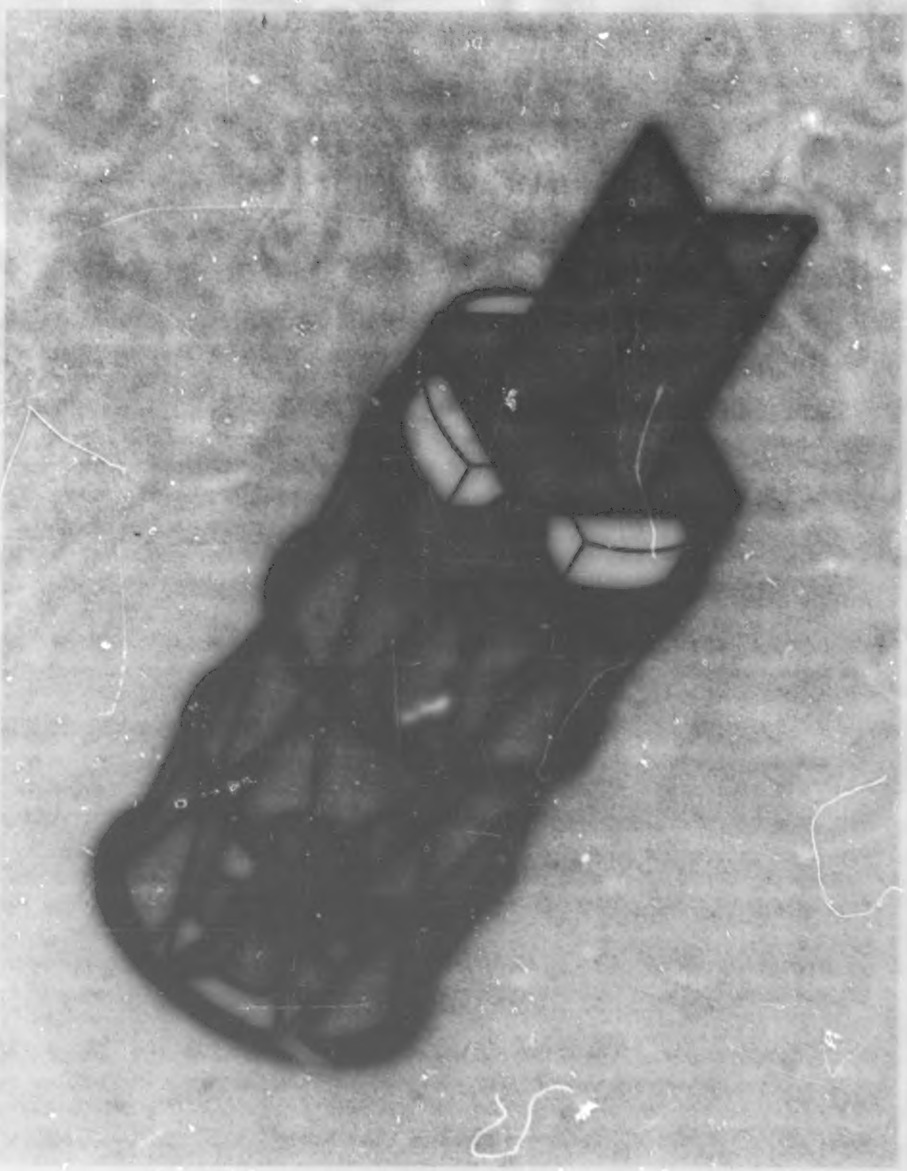
PROGRAM SCOPE

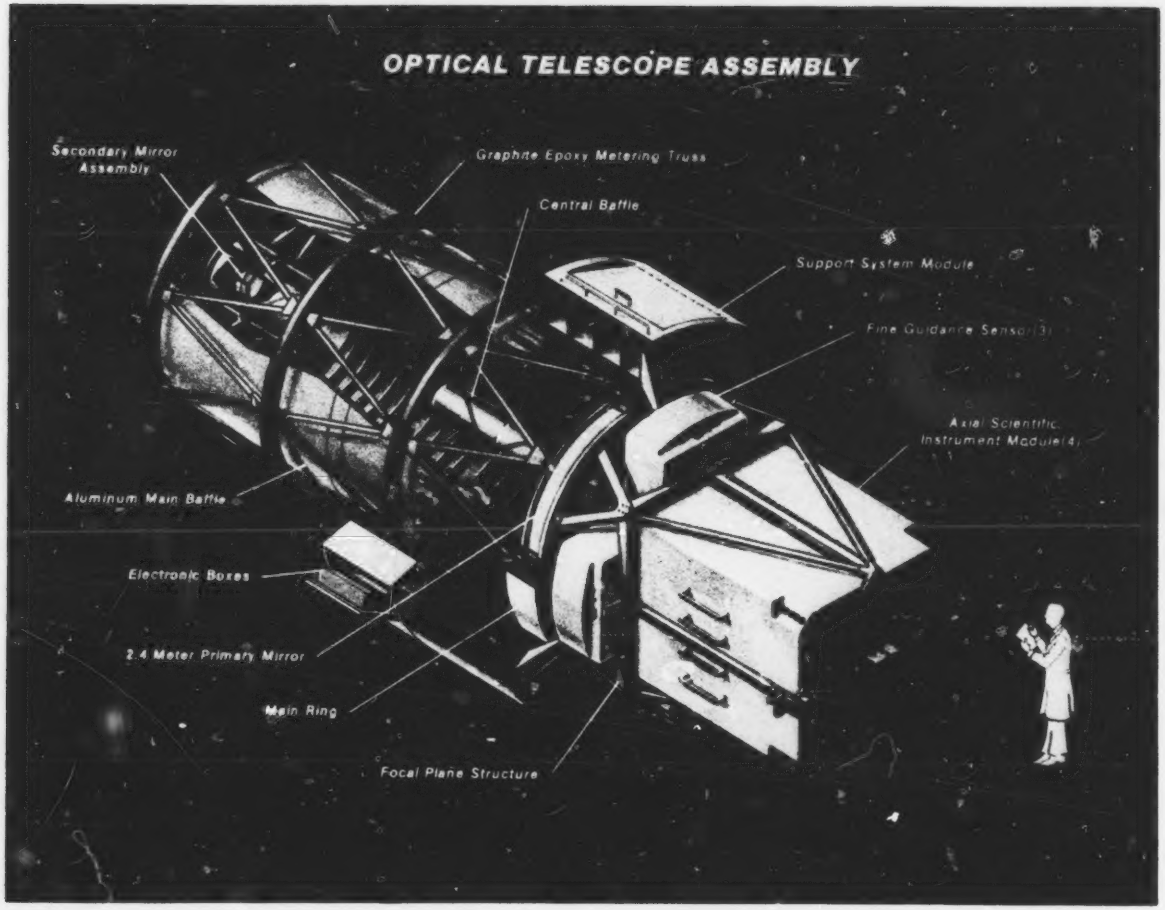
- DESIGN, BUILD AND QUALIFY ALL OTA SUBSYSTEMS (OPTICS, STRUCTURES, FINE GUIDANCE SENSOR, OPTICAL CONTROL SENSOR AND OTA ELECTRONICS)
- ASSEMBLY OF OTA AND PERFORMANCE VERIFICATION
- INTERFACING WITH SSM AND SCIENCE INSTRUMENTS
- FOCAL PLANE INTEGRATION
- SUPPORT TO LMSC, ST INTEGRATION AND LAUNCH










OPTICAL TELESCOPE ASSEMBLY
Secondary Mirror Assembly
Graphite Epoxy Metering Truss
Central Baffle
Support System Module
Fine Guidance Sensor(3)
Axial Scientific Instrument Module(4)
Aluminum Main Baffle
Electronic Boxes
2.4 Meter Primary Mirror
Main Ring
Focal Plane Structure

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TECHNICAL ACCOMPLISHMENTS

STATUS AS OF 1978 HEARING

- PRIMARY MIRROR
  - MIRROR BLANK NO. 1 NOT DELIVERED FROM CORNING, EXPECTED OCT 1979
  - DEDICATED MIRROR POLISHING/TESTING FACILITY ESTABLISHED AND READY FOR USE
  - FACILITY VERIFICATION PROGRAM INITIATED WITH 60-INCH MIRROR
- BACKUP PRIMARY MIRROR - MIRROR BLANK NO. 2 EXPECTED TO BE DELIVERED FROM CORNING, APRIL 1979
- SECONDARY MIRROR - REQUIREMENTS KNOWN
- METERING TRUSS STRUCTURE - SUBCONTRACT PLACED WITH BOEING
- FOCAL PLANE STRUCTURE - SUBCONTRACT PLACED WITH BOEING
- MAIN RING - CONCEPT STAGE
- BAFFLES - CONCEPT STAGE
- SCIENTIFIC INSTRUMENT LATCHES - CONCEPT STAGE
- FINE GUIDANCE SENSOR - DESIGN STAGE
- OPTICAL CONTROL SENSOR - DESIGN COMPLETE
- OTA ELECTRONICS - DESIGN STAGE

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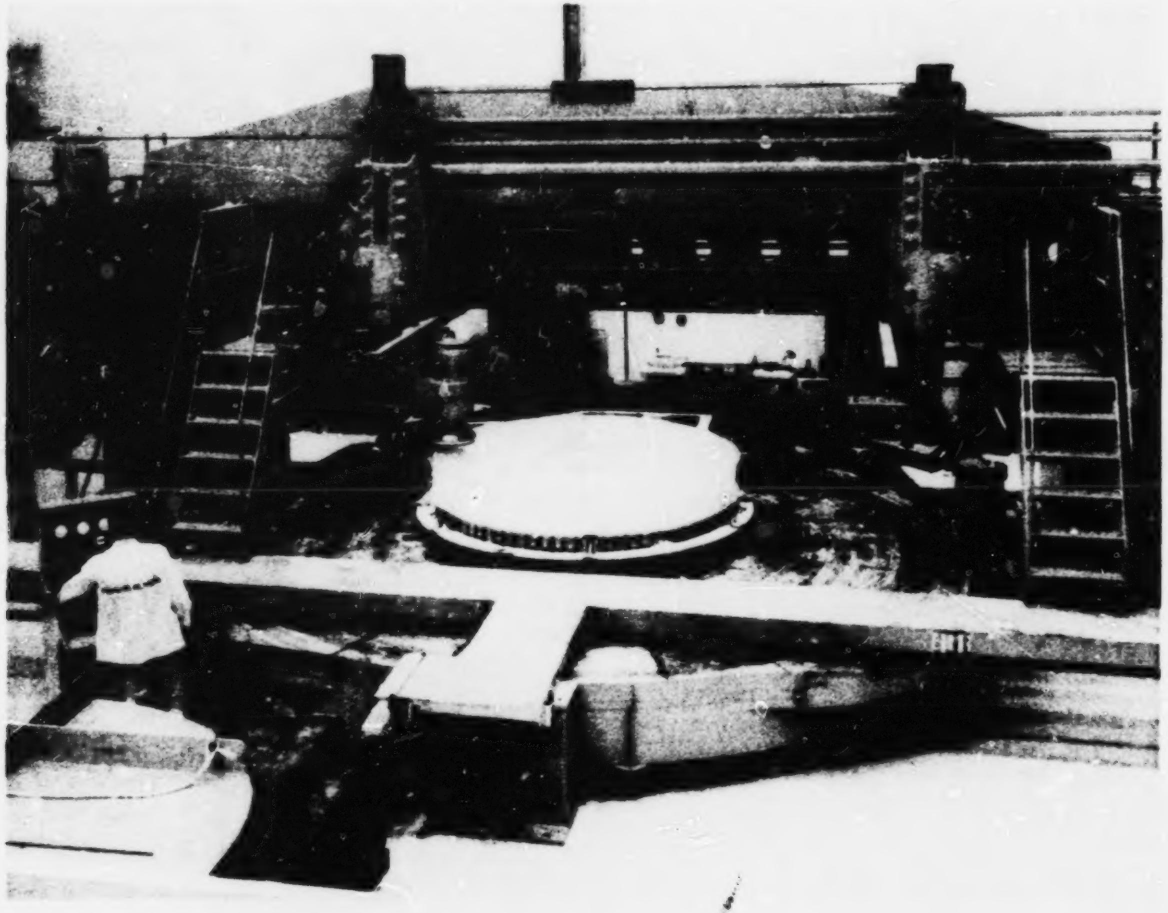
TECHNICAL ACCOMPLISHMENTS
STATUS AS OF 1982 HEARING

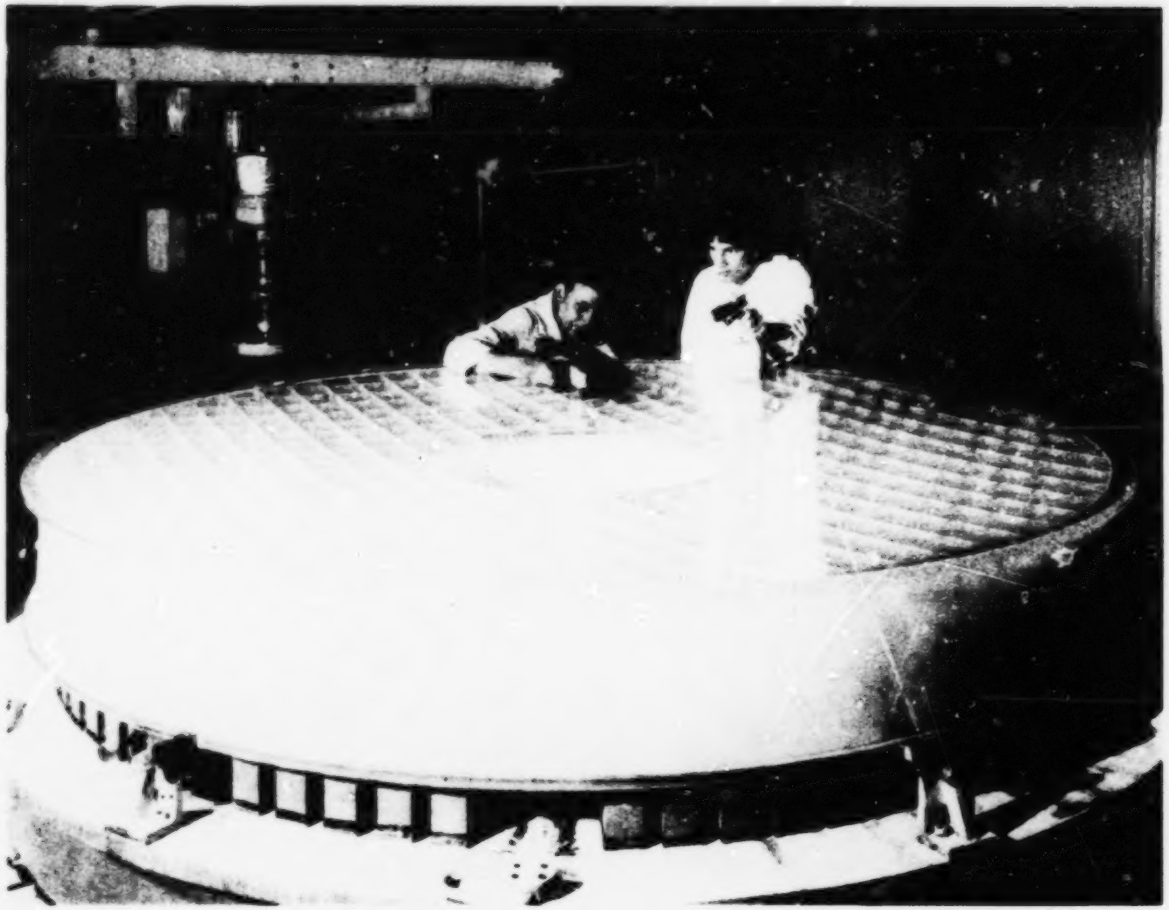
- PRIMARY MIRROR - COMPLETE
- BACKUP PRIMARY MIRROR - COMPLETE
- SECONDARY MIRROR - COMPLETE
- METERING TRUSS STRUCTURE - COMPLETE
- FOCAL PLANE STRUCTURE - COMPLETE, REQUIRES FLEXURE REWORK
- MAIN RING - COMPLETE
- BAFFLES - COMPLETE (2 OF 3)
- SCIENTIFIC INSTRUMENT LATCHES - MOST DESIGN & FABRICATION COMPLETE
- FINE GUIDANCE SENSOR - FABRICATION STAGE
- OPTICAL CONTROL SENSOR - FABRICATION STAGE
- OTA ELECTRONICS - FABRICATION STAGE

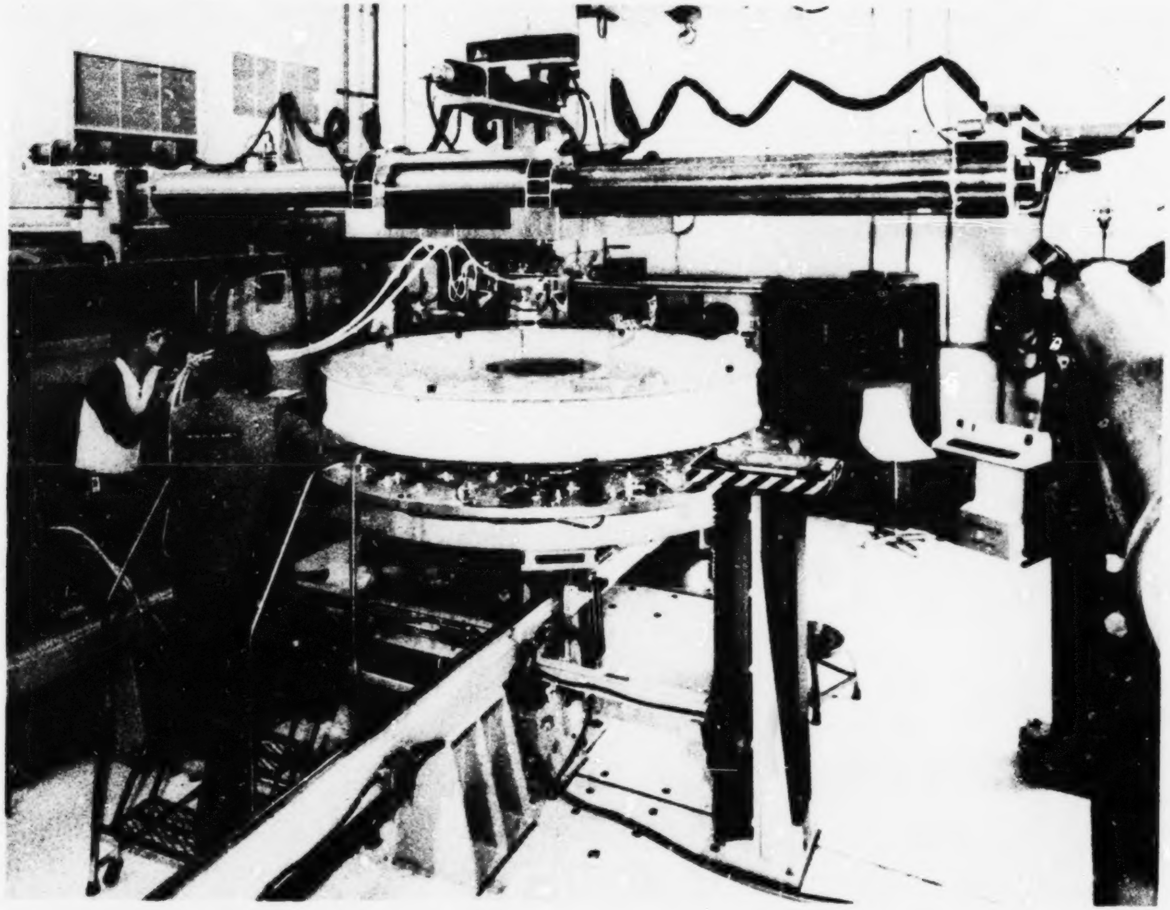
PERKIN-ELMER

PRIMARY MIRROR

- SUCCESSFUL COMPUTER CONTROLLED POLISHING OF 2.4 METER (96-INCH) MIRROR.
- BEST LARGE MIRROR IN THE WORLD – BETTER THAN $\lambda/65$ SPECIFICATION.
- REFLECTIVITY OF 89%.
- COATING CHAMBER UNIQUE.







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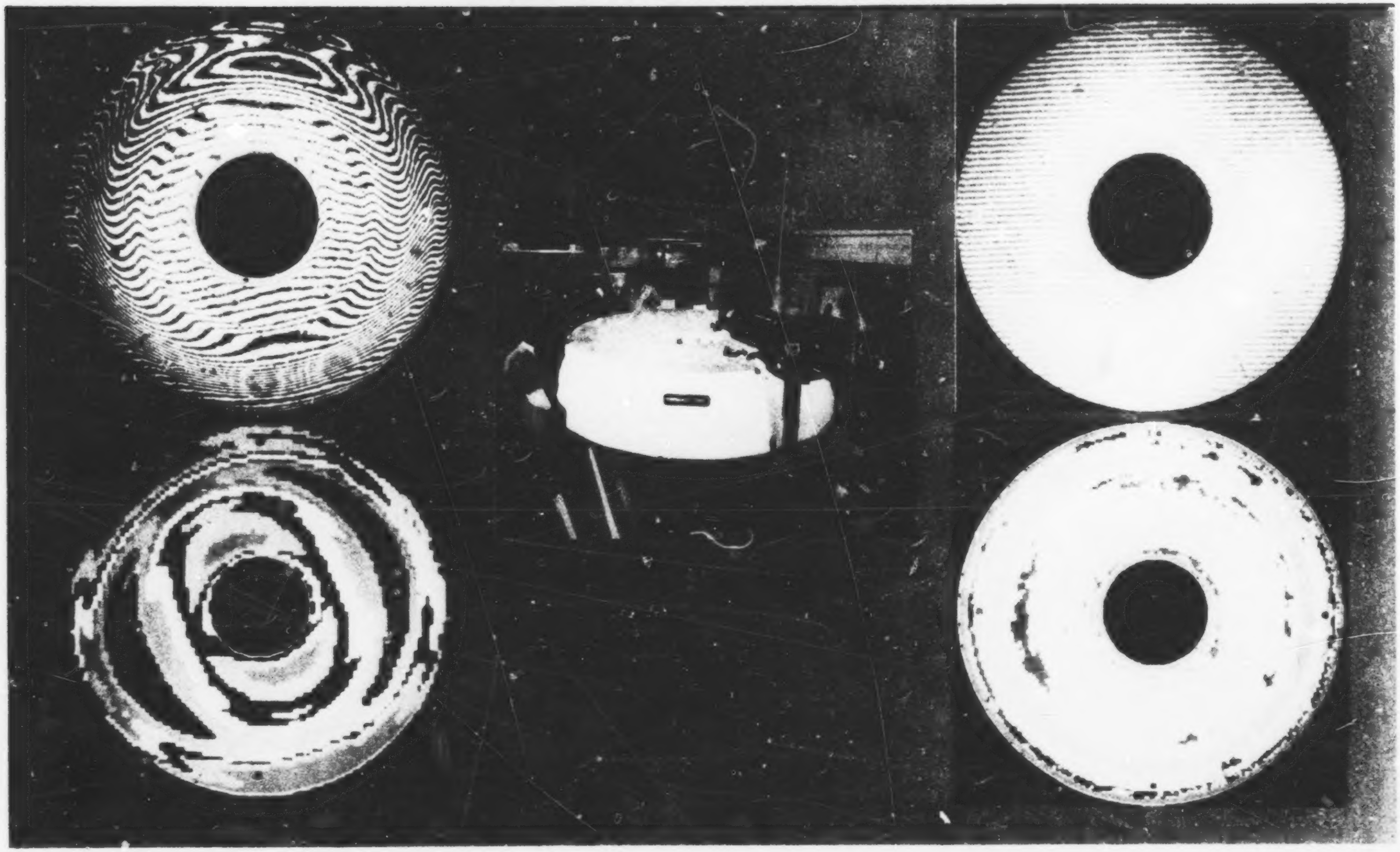
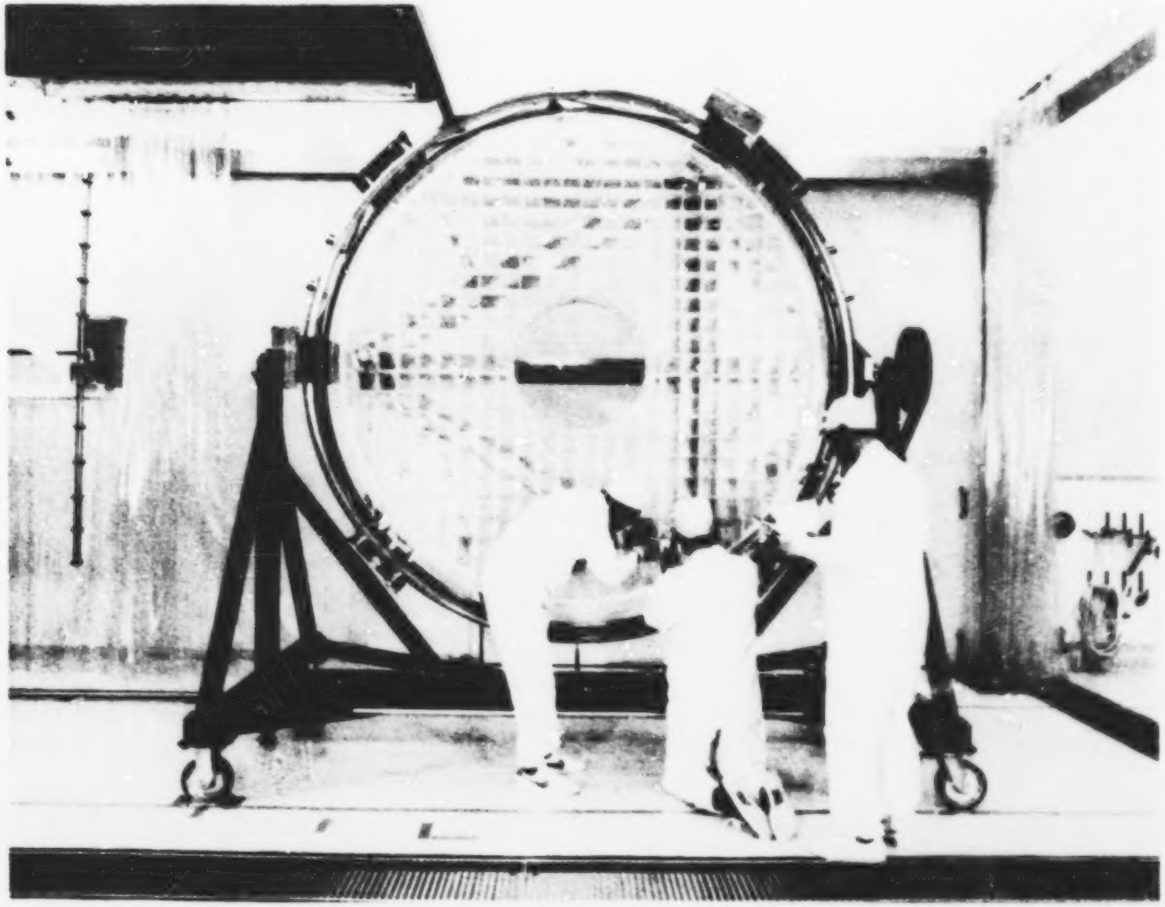
SPACE TELESCOPE PRIMARY MIRROR





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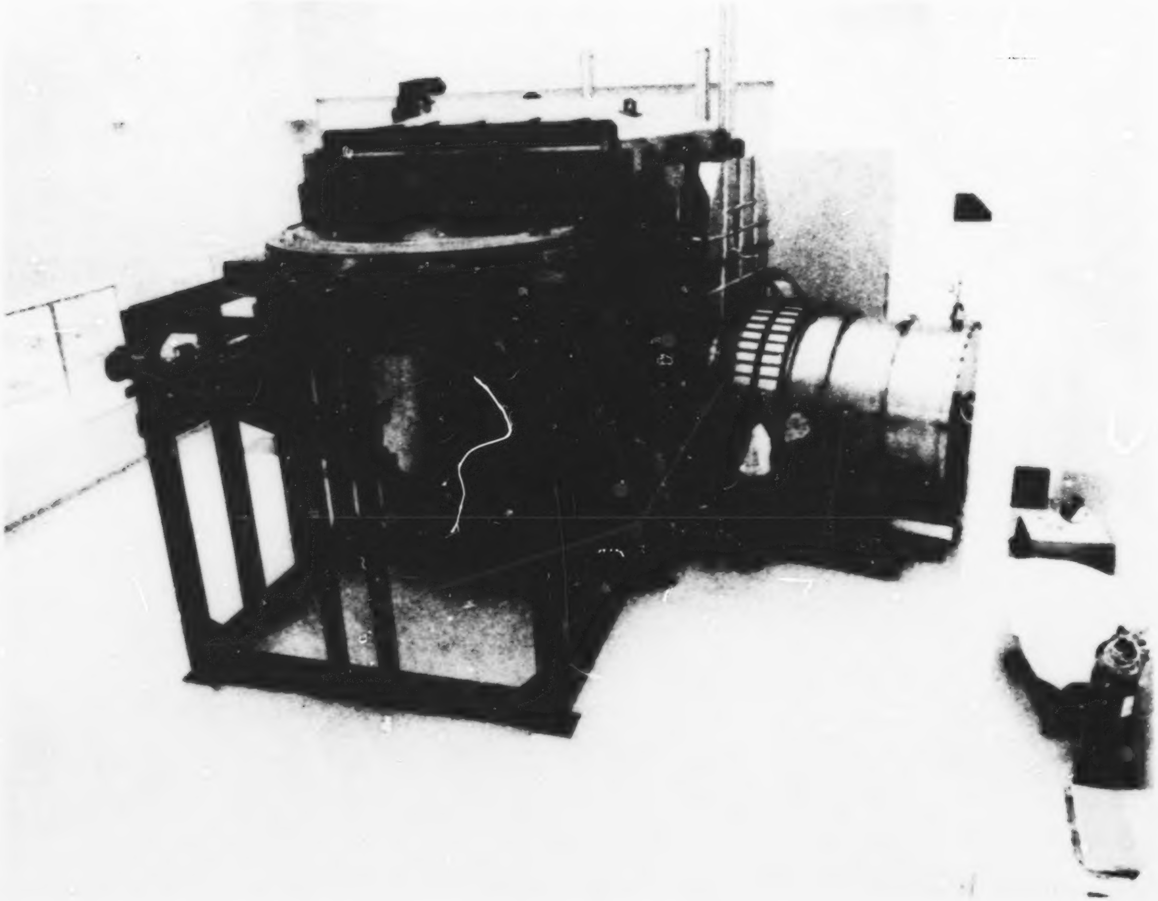

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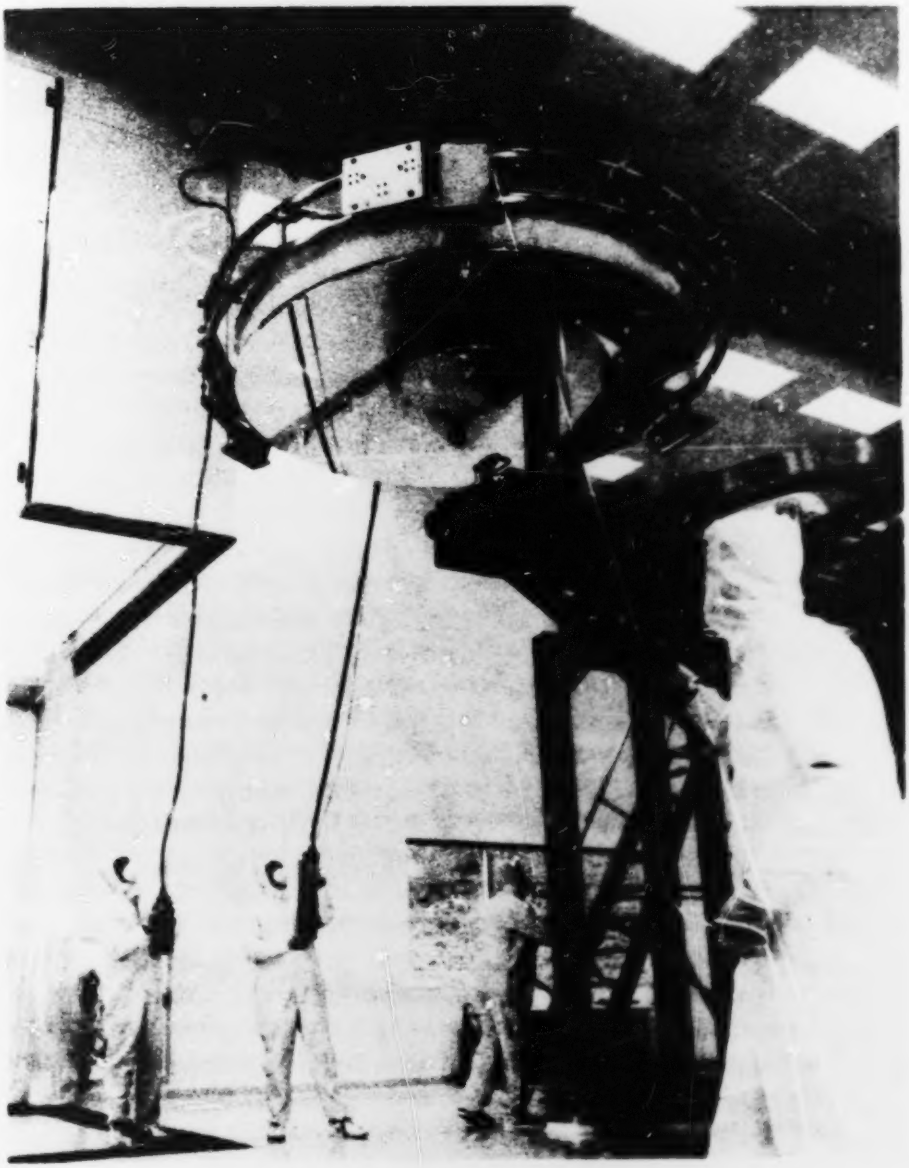

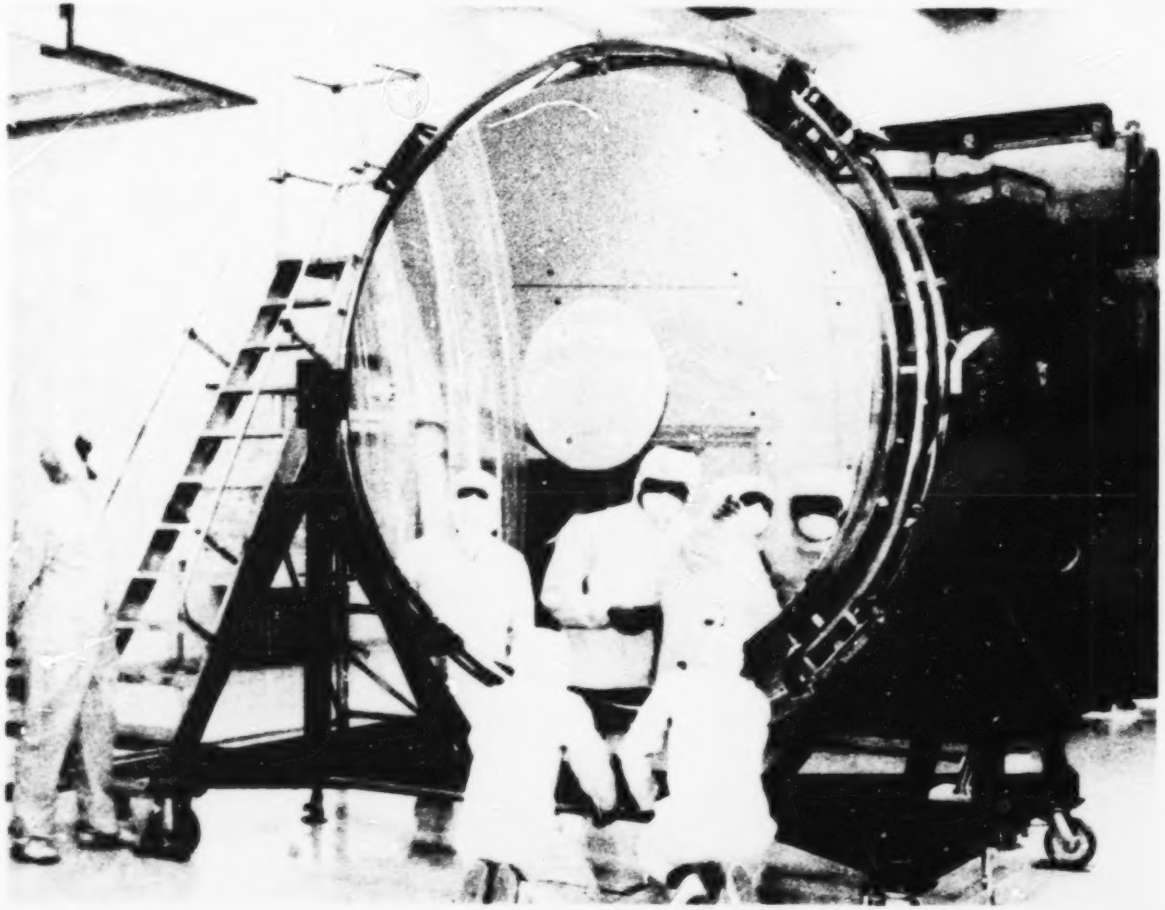

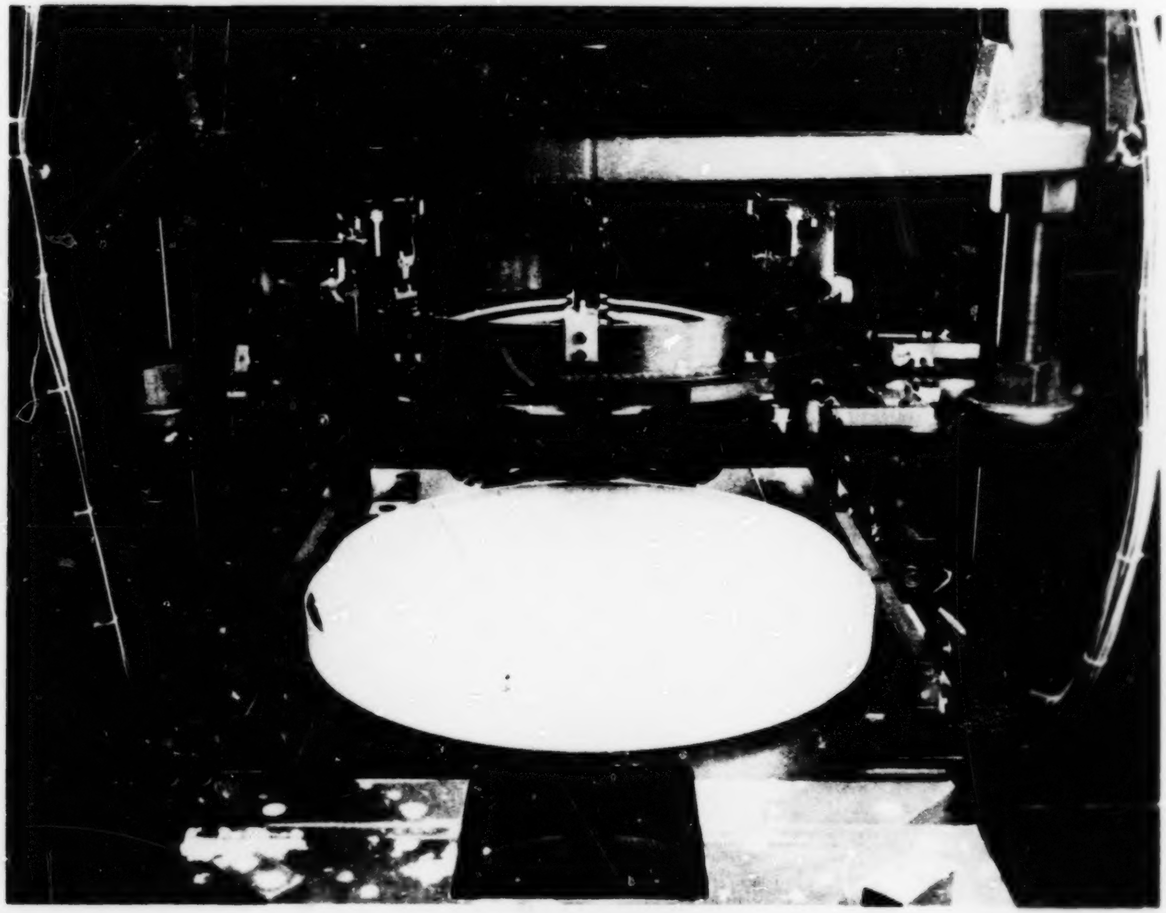

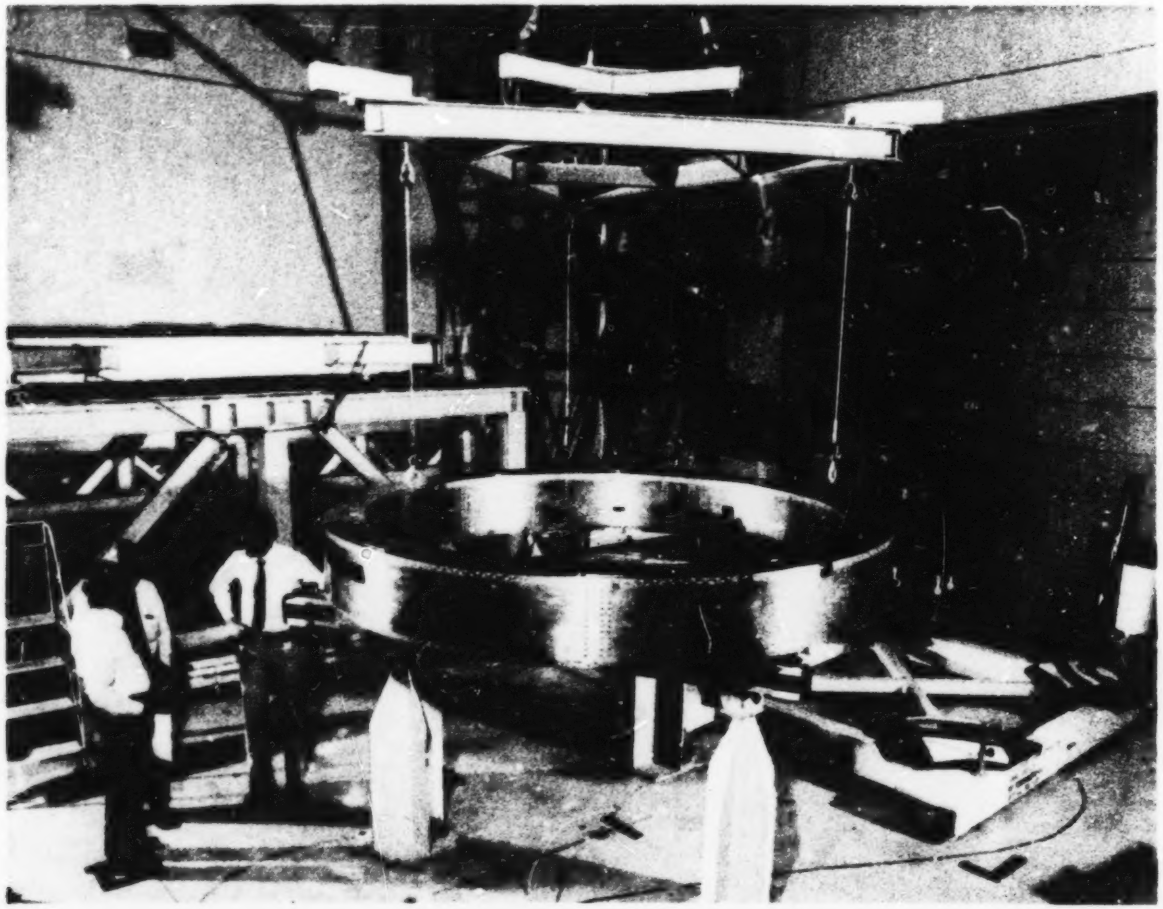

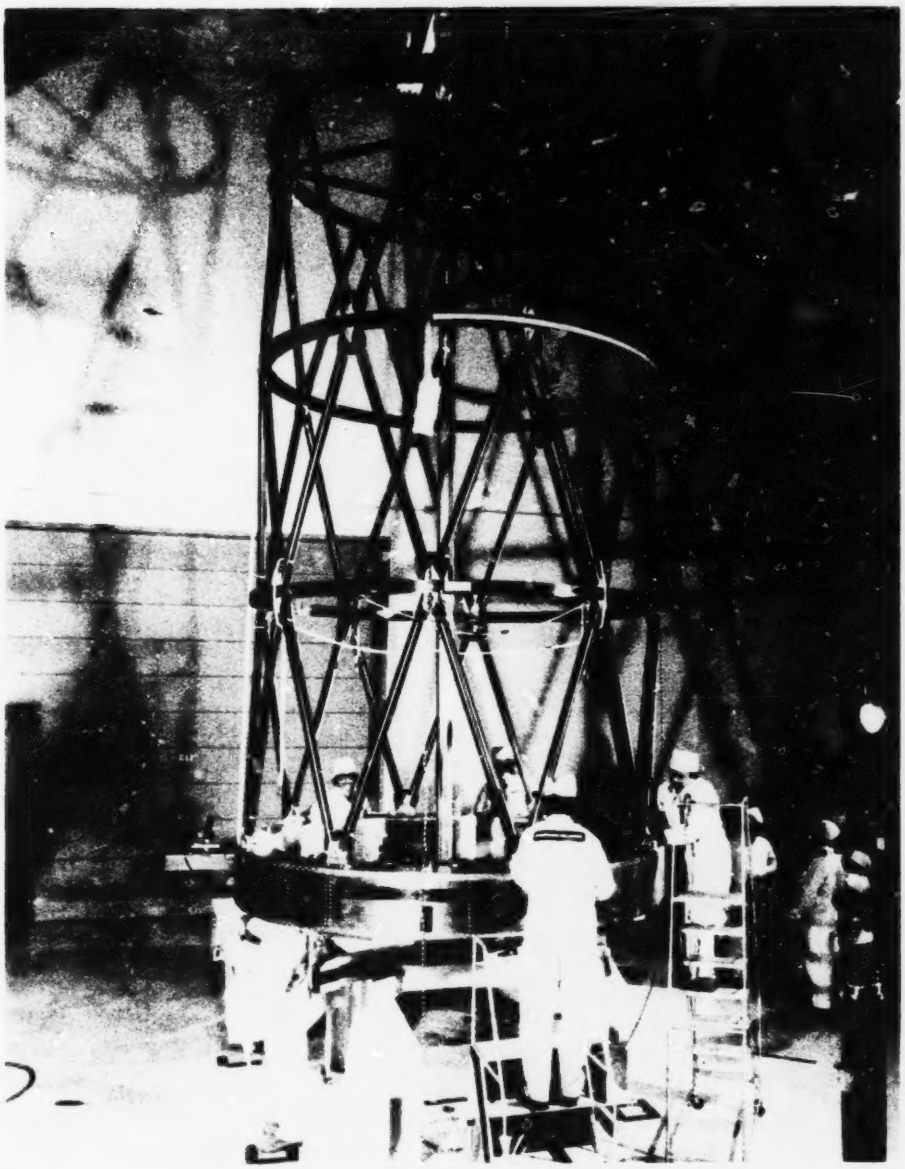

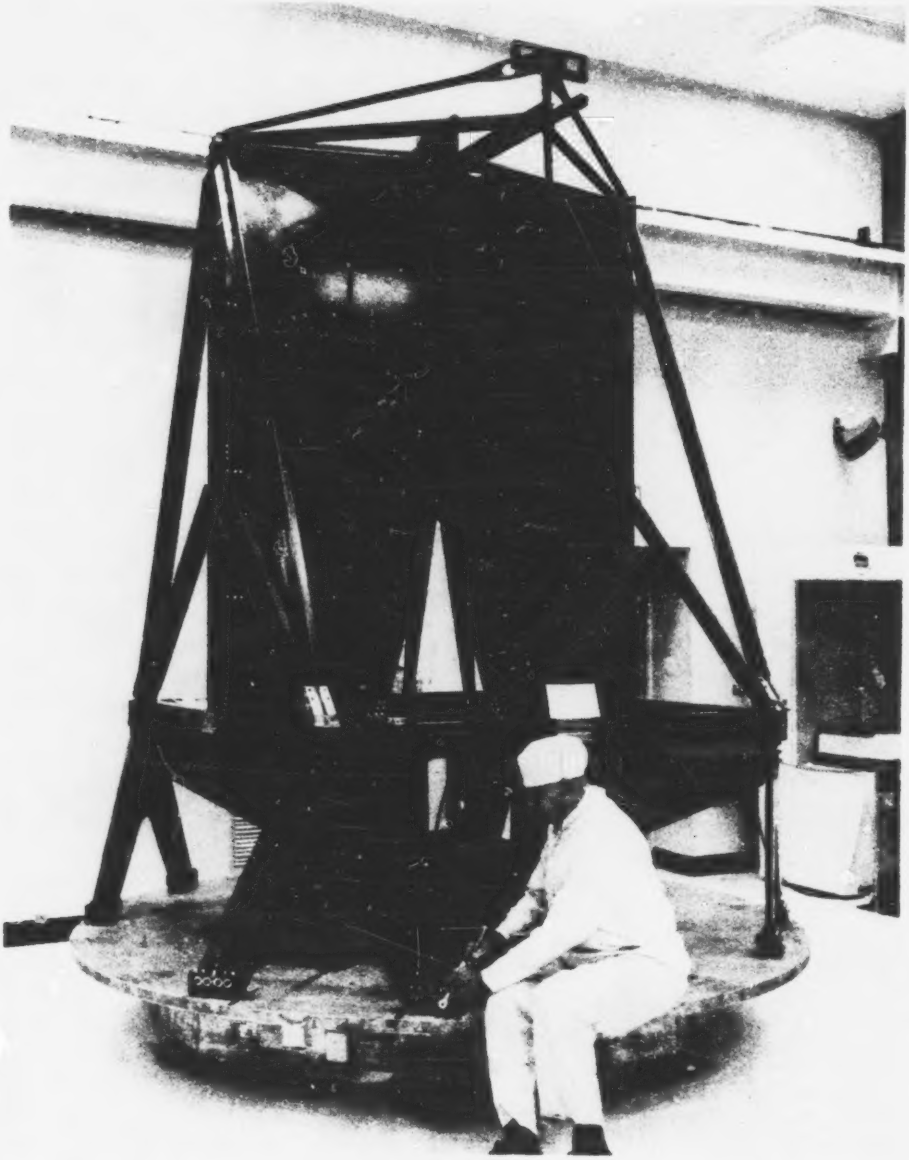

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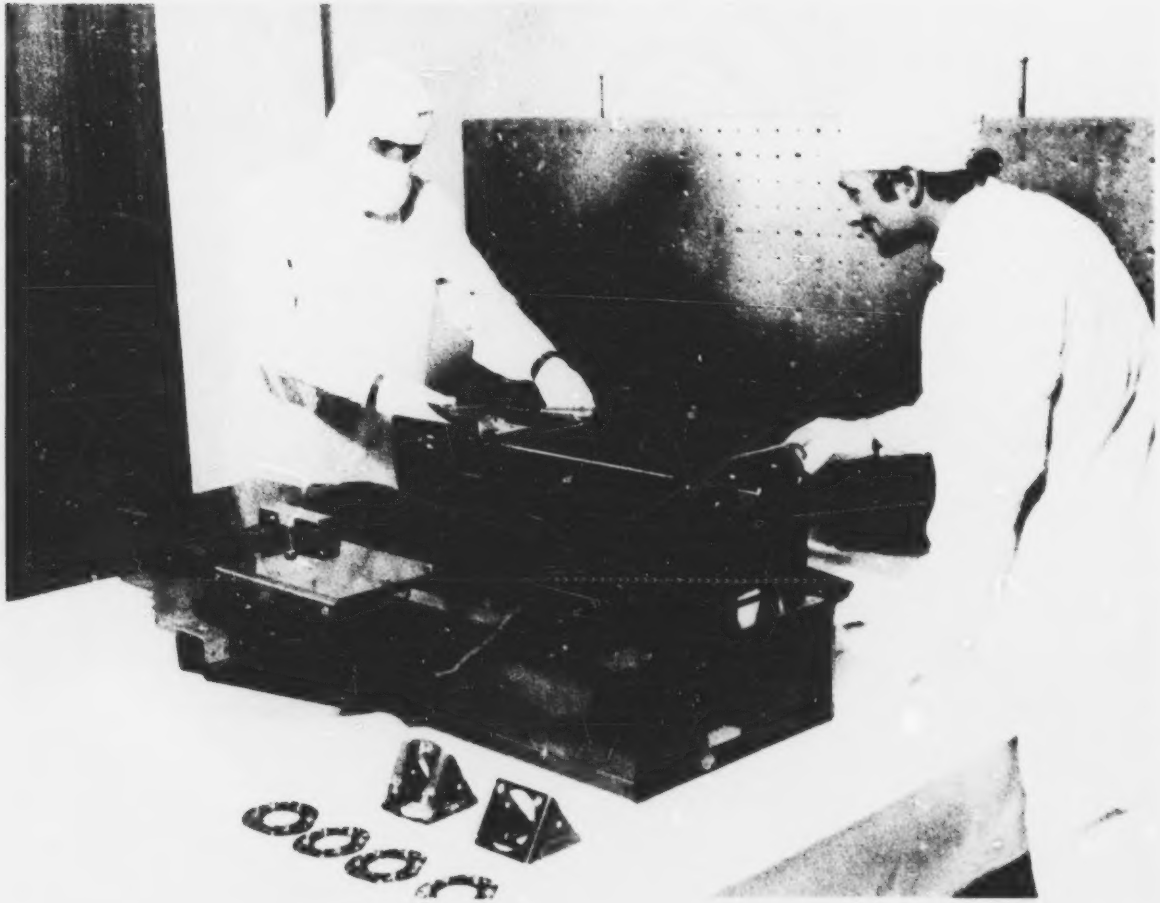

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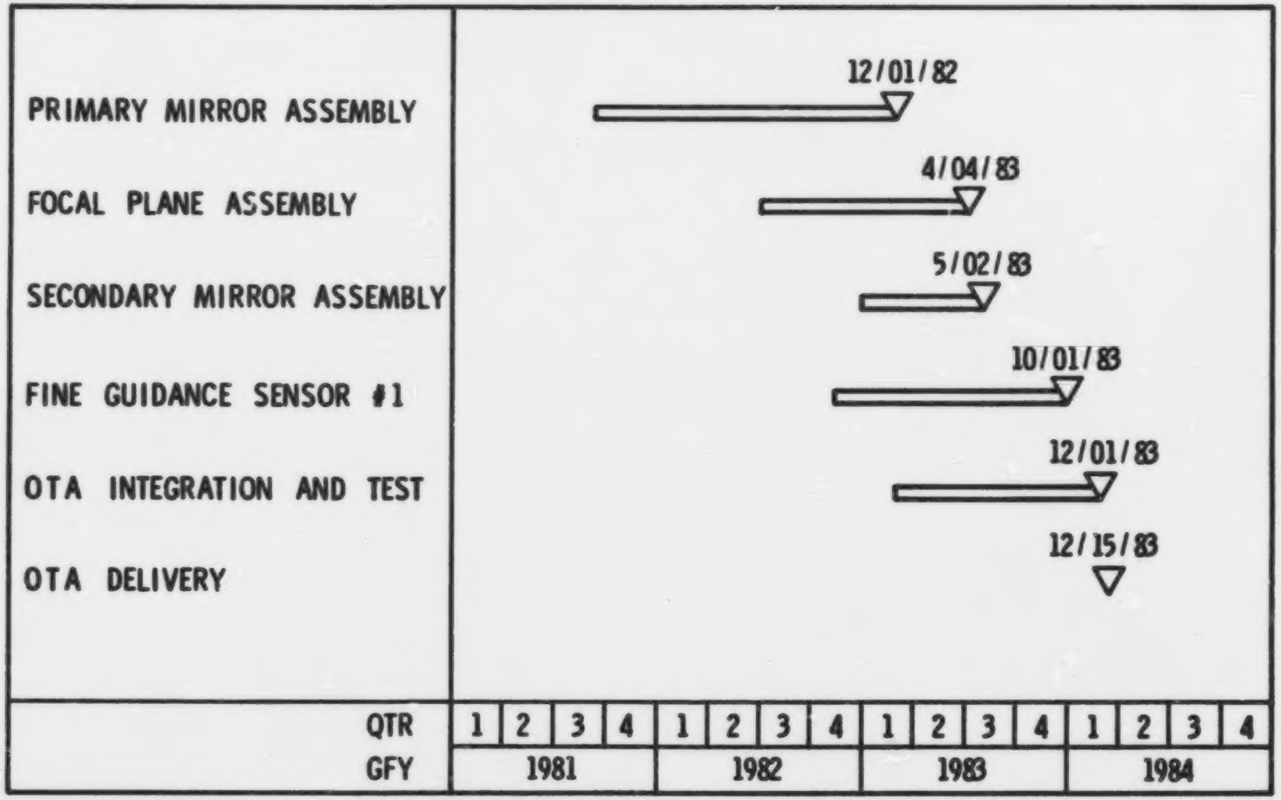
OTA MAJOR FUTURE MILESTONES



FUTURE CHALLENGES

- MAJOR ASSEMBLIES
  - PRIMARY MIRROR ASSEMBLY
  - FOCAL PLANE ASSEMBLY
  - FINE GUIDANCE SYSTEM
- FLIGHT FOCAL PLANE STRUCTURE FLEXURE MODIFICATION
- OTA ALIGNMENT
- OTA INTEGRATION AND TEST
- CONTAMINATION CONTROL

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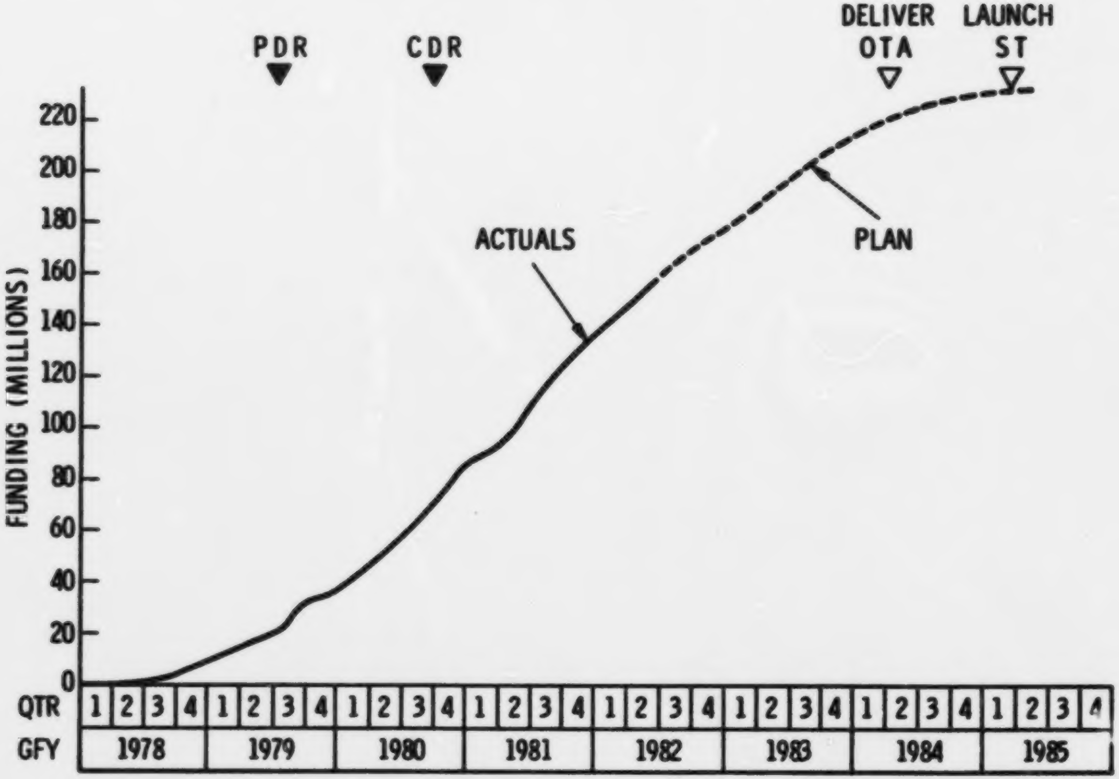
OTA PROGRAM FUNDING REQUIREMENTS



SUMMARY

- PROGRAM HAS SUCCESSFULLY TRANSITIONED TO THE HARDWARE INTEGRATION STAGE.
- FINE GUIDANCE SYSTEM DEVELOPMENT IS CHALLENGING.
- HIGH CONFIDENCE IN ABILITY TO PROGRESS THROUGH DELIVERY.
- SCHEDULE IS TIGHT BUT ACHIEVABLE.

Mr. **Flippo**. Thank you very much for your testimony.

You mentioned this was probably the finest mirror in the free world. Did you mean to exclude the nonfree world? Does anyone else have this capability?

Mr. **Rehnberg**. Mr. Chairman, to my knowledge, I don't believe so.

Mr. **Flippo**. Thank you very much.

Dr. Oder, we will receive your testimony at this time.

Dr. **Oder**. Thank you, Mr. Chairman.

I am Dr. Frederic Oder, vice president of Lockheed Corp. and general manager of the Space Systems Division of Lockheed Missiles and Space Co.

Mr. Chairman, it gives me a great deal of pleasure to be here to brief you on our progress in this important program.

The program has reached a very significant phase where, in our part, the detailed design for all the elements of the program have been essentially completed, the important interfaces have been established, and we are now entering into the manufacturing, test and verification phase. In addition, detailed requirements have been reflected on all of the associate contractors' Space Telescope hardware specifications as a proper basis for design. These requirements were validated for compliance at a recently completed Space Telescope systems review and critical design review, as Dr. Martin has stated.

As you are aware, the critical design review for the system represents an extremely important milestone which was quite satisfactorily achieved. It is my opinion that the Lockheed part of the Space Telescope program is in excellent condition. We expect to deliver our hardware and software on schedule and be ready for integrating the optical telescope assembly when it is shipped to us.

Naturally, we are very proud to be a part of the Government/industry Space Telescope team, and certainly feel that the Space Telescope represents a major step on astronomy and will lead to a quantum jump in our fundamental understanding of our universe and perhaps lead to a better understanding of the environment in which we live.

I expect that, despite the optimism that has thus far been exhibited by the science community, we have, in fact, underestimated the contribution that this program will ultimately make to our knowledge of astronomy and astrophysics. Much remains to be done, but when it is accomplished, I think we shall have a truly magnificent scientific facility on orbit.

Today, we will briefly summarize for you the cost, schedule and performance aspects relating to the Lockheed Missiles and Space Co. development activities for the Space Telescope Program. Accompanying me today is Bill Wright, vice president, NASA Programs at Lockheed Missiles and Space Co., who will present to you an overview of our progress and accomplishments together with our future plans. In addition, Bert Bulkin, Space Telescope program manager, will accompany Bill during the question and answer period following our formal statement.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Oder follows:]

STATEMENT OF
DR. FREDERIC C. E. ODER
VICE PRESIDENT AND GENERAL MANAGER
SPACE SYSTEMS DIVISION
LOCKHEED MISSILES & SPACE COMPANY, INC.

BEFORE

THE SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATION
COMMITTEE ON SCIENCE AND TECHNOLOGY
U. S. HOUSE OF REPRESENTATIVES

Gentlemen, it gives me a great deal of pleasure to be here before your committee again to brief you on our progress to date on the Space Telescope Program.

The project has now reached a significant phase wherein the detailed design for all the elements of the program have been essentially completed, interfaces have been established and we now enter into the manufacturing, test and verification phase. In addition, detailed requirements have been reflected in all of the associate contractor's Space Telescope hardware specifications as a basis for design. These requirements were validated for compliance at a recently completed Space Telescope Systems Review and Critical Design Review. As you are aware, the Critical Design Review for the system represents an extremely important milestone which was satisfactorily achieved. It is my opinion the Lockheed part of the Space Telescope Program is in excellent condition. We expect to deliver our hardware and software on schedule and be ready for integrating the Optical Telescope Assembly when it is shipped to us.

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Mr. **Flippo**. Thank you.

We are pleased to have you Bill.

Mr. **Wright**. Good morning gentlemen. I am delighted to be here again to discuss with you the overall status of the Space Telescope program, from the Lockheed point of view. My statement today will include the highlights of our past accomplishments, our present hardware status, our future plans, as well as a description of our new facilities. We will wind up by discussing our cost projections and funding requirements.

The first chart is an artist's conception of the Space Telescope as it would appear in orbit. As you all know, it is an International Astronomical Observatory consisting of a 2.4 meter optical telescope, 43 feet long, 14 feet in diameter. The thing we have to keep in mind is that it is the first payload for the Shuttle which will have been designed with the Shuttle in mind. The Shuttle will conduct the initial deployment, perform contingency and routine maintenance, and participate in retrieval and return to Earth.

The next chart illustrates the total ST system encompassing all the major elements of that system. There are five major elements that we must always keep in mind: the Shuttle; the observatory itself; the tracking and data relay satellites, two of those; the Operations Control Center at Goddard; and the Science Institute. All of those elements have to be properly integrated, interfaced and functioning properly in order to realize the maximum scientific potential of the system.

Lockheed's responsibility as a part of the overall ST project includes four basic areas: ST system engineering, which assures system compatibility among these elements I just talked about; the design and development of the support system module, which includes integrating the European-supplied solar arrays; ST integration, including the assembly, test, and verification of the complete ST observatory; and finally, mission operations support, which includes launch preparation, checkout, orbital verification. Recently, Lockheed has been placed under contract for continuing mission operations support after the launch.

The next chart illustrates our overall schedule, together with the key delivery dates of all the associate contractor hardware to Lockheed for the subsequent environmental testing of the entire ST observatory. As you can see from the chart, the critical design review was conducted in March of this year to address compliance of all the ST elements with contractor end items specifications. In addition, the support systems module CDR was conducted at the same time.

Prior to this critical design review, in 1981, the systems review was held to address compliance of all the ST elements to the scientific performance and interface requirements. The basic conclusion that we and NASA have reached, as well as our associate contractors, from these important reviews is that the project requirements and the support systems module design status certainly support the readiness for the next phase, the manufacturing and verification phase.

We at Lockheed are on schedule to that present plan shown in this chart. We are confident that the subsequent milestones will be met for downstream hardware fabrication and assembly. The key dates in our downstream planning, however, are dependent upon the delivery of all of the associate contractor hardware. I will discuss those briefly as follows: The European-supplied solar array in August of 1983; the scientific instruments, five of them, as well as the optical telescope assembly, November and December of 1983 respectively.

Other key dates for our downstream plan is the initiation of the support systems module assembly in March of 1983, and start testing of that assembly in October; initiate the overall ST assembly in 1984; together with environmental testing in May of 1984.

The next chart lists the major schedule accomplishments of the past year. As mentioned earlier by Dr. Martin, the most significant milestone accomplished has been the completion of the systems review as well as the support systems module and Space Telescope CDR's. Another noteworthy accomplishment, in our view, is that all the interface control documents for all the modules in the Space Telescope, as well as the elements of the system, have been baselined and are now under configuration control by NASA/MSFC.

Of special significance was the initiation of an improved gyro by incorporating a shroud in the gyro which will enable us to meet the pointing requirements which Dr. Martin referred to of .007 arc seconds. The actual performance at the present time is .008 arc seconds, which is better than what we have been committed to, to give the scientists. The engineering performance verification of a flight prototype consisting of functional environmental tests has been completed for this gyro. That is of special significance to us.

A key part of our data management subsystem is the data management unit which interfaces the computer to the rest of the Space Telescope. This is a rather large complex electronic unit built by Lockheed. The successful completion of the development testing is of significance, proving the basic coherence of our data management concept. The initial delivery of flight hardware was accomplished during this period; all of these are subcontract hardware and are similar to the hardware utilized by other Lockheed programs.

This chart depicts the major equipment which is shown with the equipment section. The support systems module is divided into four major sections: the light shield, which provides protection for the optical telescope assembly; the forward shell, which is also light-tight and supports the solar array; high gain antenna mounting; and carries the trunnion fittings which interface with the Shuttle orbitor.

The equipment shown here houses most of the basic data management equipment, electrical power control equipment, certain pointing control equipment, and communication electronics. As you can see, the fixed head star trackers and the gyros are mounted on the focal plane to assure overall accuracy and alinement.

All of these equipments are either flight equipment already delivered or flight prototype engineering models utilized for qualification and verification of the design. The flight equipments already delivered are the computer from Rockwell International in Anaheim, Calif.; rotary drives from Schaeffer Magnetics from Chatsworth, Calif.; and the transponders from Motorola in Scottsdale, Ariz. All our remaining electronic equipments will be delivered by August of 1983.

The next chart shows four major structural segments of the support systems module which were utilized early in the program for acoustic testing to stimulate the environment of the Shuttle and its effect on the design of the equipment and their installation, as well as being utilized for the Shuttle crew interface with our orbital replacement units. All of this environmental information was passed on to all of our associate contractors and incorporated in their interface control documents. This structural replica of the Space Telescope has been updated and will now be utilized as a low-cost manufacturing tool for fabricating all of the Space Telescope wire harnesses.

This next chart shows the equipment section, one of those four sections, which has been modified and updated to reflect our present design, and it shows the installation of all mockups of our equipment sections where we will install the actual flight wire harness utilizing the mockups of the boxes installed in the equipment section.

This approach conceived by us in the fabrication of flight wire harnesses provides an extremely low-cost alternative to extensive documentation, as well as an alternate extremely expensive three dimensional form boards that would be required in the fabrication of approximately like 20,000 wires.

The next chart shows our first major flight structure produced by Lockheed. This structure is the optical telescope assembly equipment section which is mounted forward of the support systems module section and houses all of the Perkin-Elmer designed equipment. It also provides for thermal protection for the Perkin-Elmer built hardware. Of special significance to us is that the manufacturing cost for tooling and fabrication have been followed very closely and is tracking very close to our projections, in which case we use that to validate our cost projections for the major flight structure yet to be fabricated.

The next chart shows our automated test software computer facility. Utilization of this facility continues our present experience of minimizing system test costs and time by providing the capabilities to pre-validate all our test procedures by simulation before actual testing commences. Also derived from these simulations are predicted spacecraft responses to the test sequences, thus allowing all system parameters to be monitored in real time to pre-established limits.

The system will handle data rates up to a million bits per second. Up to 13 user cathode ray tube data display stations are supported with update rates of 1 to 5 seconds. The central computer system consists of two Digital Equipment Corp. computers with standard peripherals which provides for the pretest real time and posttest processing. The engineering data base development from this activity is being delivered on an incremental basis to Goddard Space Center for their operations with their ground systems software development, as well as their associate contractor activity. It is the plan that this entire computer complex will be installed in our new Space Telescope vertical assembly and test facility which is shown on the next chart.

This is a new building constructed and funded by Lockheed which will serve as both the support systems module and Space Telescope final assembly and test facility at our Sunnyvale, Calif. complex. This facility will be ready for use at the beginning of next year. It is one of the world's largest horizontal laminar flow cleanrooms for spacecraft integration. It also houses the necessary support facilities to house equipment and people, not only for Lockheed, but for our associate contractors, in addition to the Europeans who will be there for the testing.

The cleanroom is 50 feet wide, 120 feet long, and 85 feet high. It handles class 10,000 clean-room requirements using a horizontal laminar flow system.

The contiguous support facility contains 47,000 square feet of desk and board and support operations space, including 19,000 square feet contiguous to this facility for our test software computer system consisting of the two Digital Equipment Corp. computer systems you saw in the previous chart called VAX 11/780's.

The new cleanroom opens within the same building and gives access to our already existing vertical acoustic test chamber and horizontal thermal vacuum test chamber, which is provided for this program and is also utilized with some of our other programs.

The last chart summarizes fiscal year 1982 cost plan, together with the actual expenditures to date. Our costs expended at the present time are $119.3 million as compared to our plan of $120.2 million. We are in a slightly underrun position to our cost projection. However, late subcontractor billings, together with a modest acceleration of our manufacturing buildup, should have us right back to our projected figures by mid-June. We are confident that we will meet our guidelines for the remainder of this year. Also shown on this chart are our funding requirements for the outyears for completion of the program.

Dr. Martin mentioned earlier that fiscal year 1983 is a big year for us, as well as our other associates, and that the incremental $46.7 million for the fiscal year 1983 is a very important number for us because we must have that funding to maintain our schedule.

To summarize, gentlemen, we are on schedule within our projected costs and we are performing well. We are looking forward to the next phase of the program in completing fabrication of the flight hardware, assembling the support systems module and conducting our Space Telescope environmental testing leading to a fully tested Space Telescope to be delivered to Kennedy Space Center for integration into the Shuttle in December of 1984.

Thank you.

[The prepared statement of Mr. Wright follows:]

STATEMENT OF
MR. WILLIAM F. WRIGHT
VICE PRESIDENT, NASA PROGRAMS
LOCKHEED MISSILES & SPACE CO., INC.

FOR THE

SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS
COMMITTEE ON SCIENCE AND TECHNOLOGY
U. S. HOUSE OF REPRESENTATIVES

Gentlemen, I am delighted to be here again to discuss with you the overall status of the Space Telescope Program. My statement today will cover the highlights of our past accomplishments, present hardware status, and future plans together with a description of our new facilities, and conclude with an overview of our cost and funding requirements.

Figure 1 is an artist's conception of the Space Telescope (ST) as it would appear in orbit. The Space Telescope is an International Astronomical Observatory consisting of a 2.4 meter optical telescope which will be placed in a nominal 300 nautical mile orbit by the Space Shuttle in early 1985. It weighs approximately 24,000 pounds; it is 14 feet in diameter, and 43 feet long. This will be the first payload for the Shuttle which will have been designed with the Shuttle in mind whereby the Shuttle crew will conduct the initial deployment, perform contingency and routine maintenance, and participate in retrieval and return to earth.

Figure 2 illustrates the total ST system encompassing all the major elements of that system. There are five major elements, namely, the ST Observatory, the Space Shuttle, the Tracking and Data Relay Satellites (TDRSS), the ST Operations Control Center, and the Science Institute. The ST Observatory has three major modules namely the Optical Telescope Assembly (OTA), the Scientific Instruments (SI), and the Support Systems Module (SSM).

Lockheed's responsibility as a part of the overall ST project includes four basic areas, namely ST Systems Engineering which insures system compatibility

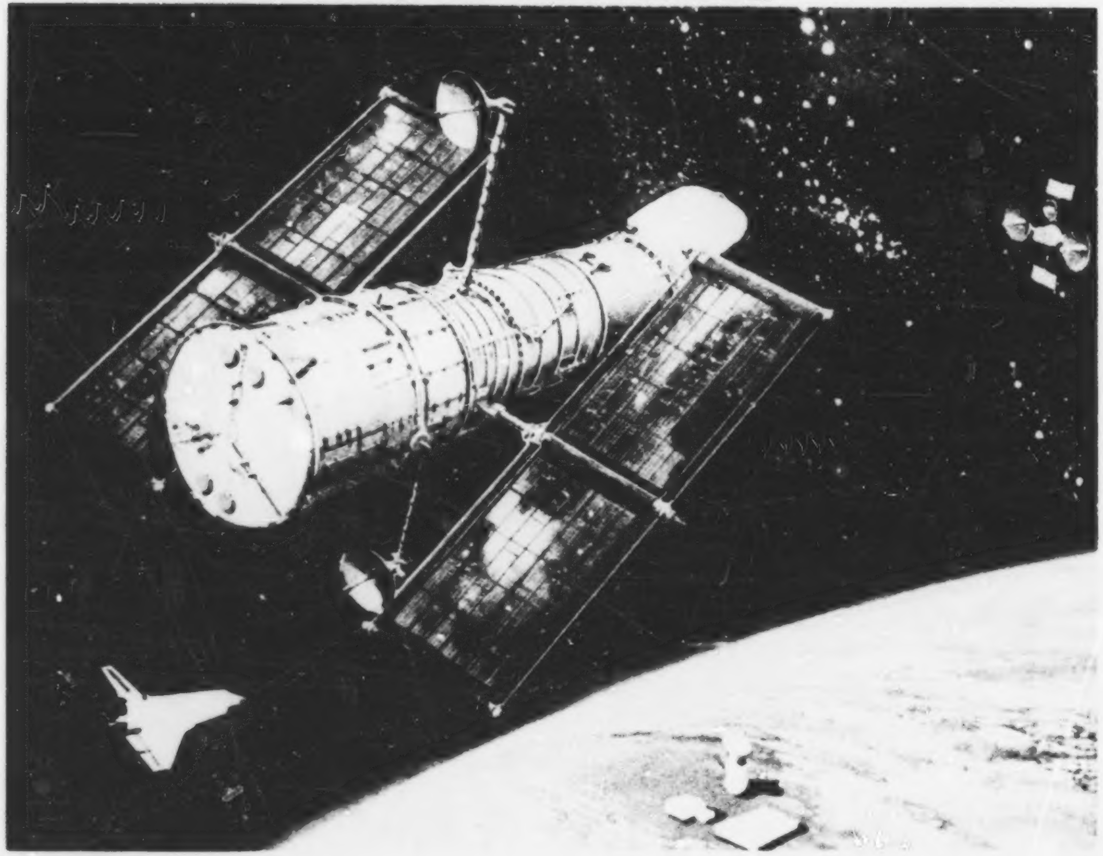


Figure 1

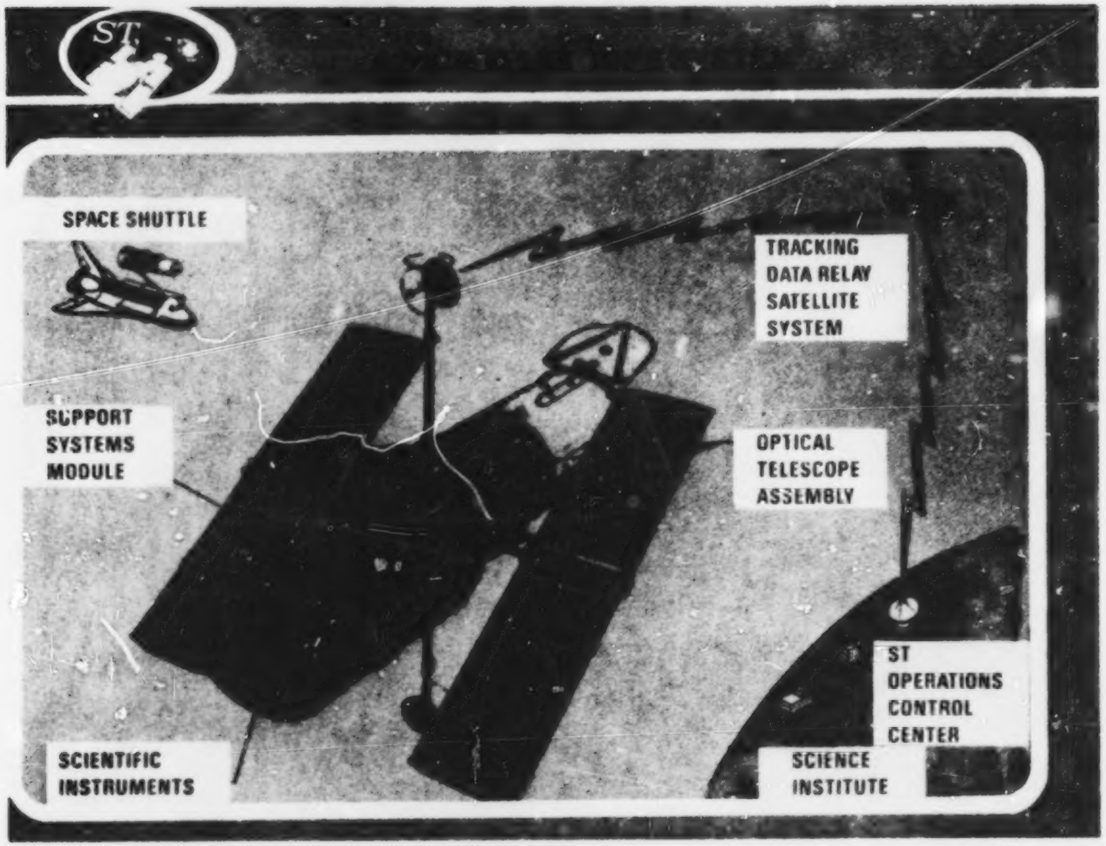

ST
SPACE SHUTTLE
TRACKING DATA RELAY SATELLITE SYSTEM
SUPPORT SYSTEMS MODULE
OPTICAL TELESCOPE ASSEMBLY
ST OPERATIONS CONTROL CENTER
SCIENTIFIC INSTRUMENTS
SCIENCE INSTITUTE

Figure 2

among all the ST system elements; the Design and Development of the Support System Module which includes integrating the European-supplied Solar Arrays, ST integration including the assembly, test and verification of the complete ST Observatory, and finally, mission operations support which includes launch preparation, checkout, orbital verification. Recently, Lockheed has been placed under contract for continuing mission operations support after launch.

Figure 3 illustrates our overall schedule together with the key delivery dates of all the associate contractor hardware to Lockheed for subsequent environmental testing of the entire ST Observatory. We have reached a significant phase in our program where the detailed design of the SSM is essentially complete and we are now in the fabrication and assembly phase. The Critical Design Review (CDR) was conducted in March of this year to address compliance of all ST elements with all contractor end item specifications. In addition, the SSM CDR was conducted at the same time. Prior to the CDR, an ST Systems Review was held last year to address compliance of all ST elements to ST Scientific performance and interface requirements. The basic conclusion reached from these important reviews was that the ST design continues to comply with the ST project requirements and that the SSM design status supported the readiness for the SSM manufacturing phase. Lockheed is on schedule to the present plan outlined in Figure 3 and we are confident that the subsequent milestones will be met for the downstream hardware fabrication, and assembly/test activities for both the SSM and the ST. The key dates in our downstream planning for delivery of associate contractor hardware to Lockheed in preparation for assembly and testing of the entire Space Telescope is as follows: the European supplied Solar Array in August 1983; the Scientific Instruments and the Optical Telescope Assembly in November and December 1983 respectively. Other key dates are: initiation of SSM assembly in March 1983, start SSM test October 1983; initiate ST assembly in January 1984; and start ST environmental testing in May 1984 leading to the shipment of ST to Kennedy Space Center in December 1984 in preparation for launch in January 1985.

Figure 4 lists the major schedule accomplishments of the past year. As mentioned earlier, the most significant milestone accomplished has been the completion of the Systems Review and the SSM and ST CDRs. Another

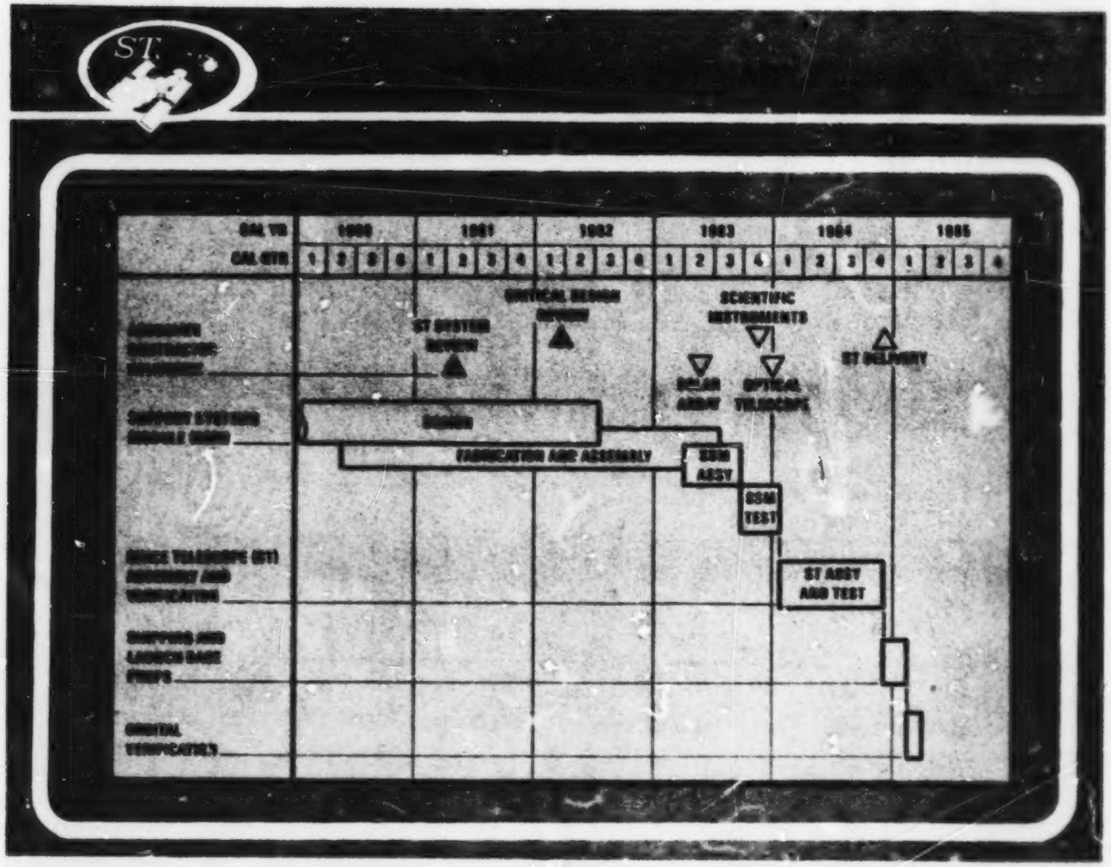
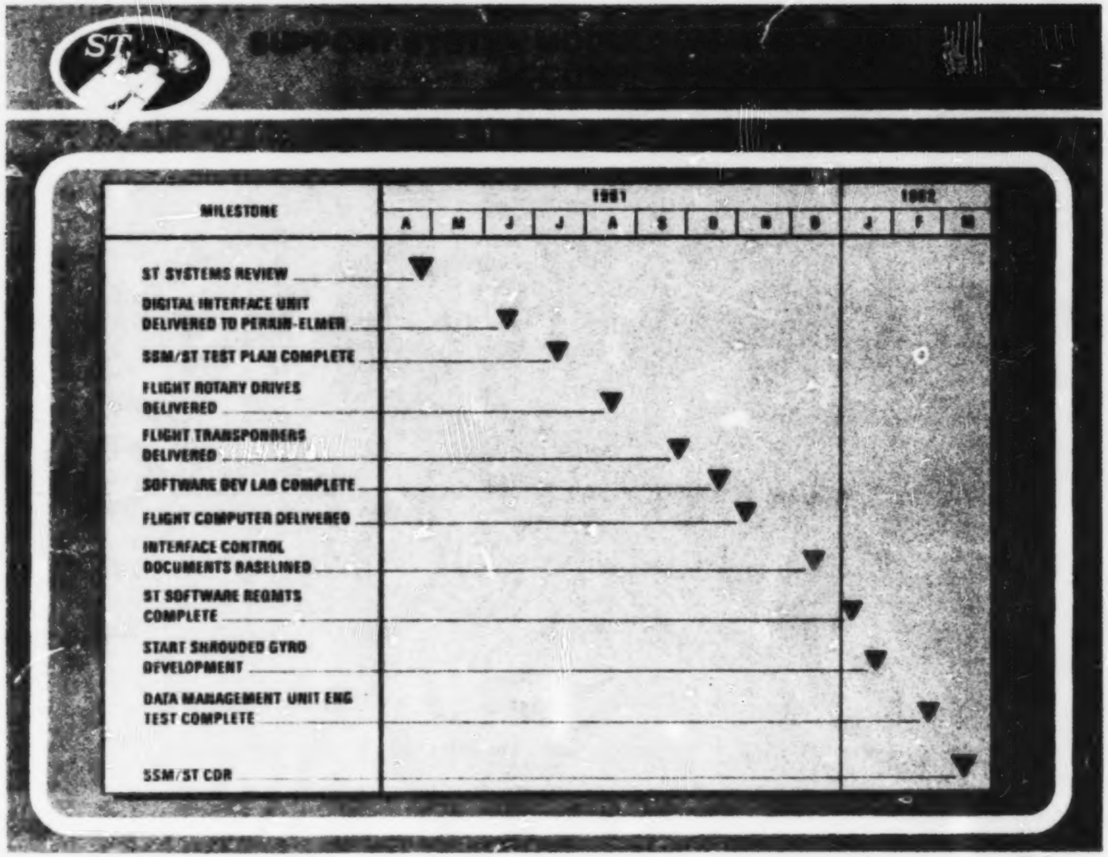

ST
CAL YR
CAL QTR
1980
1981
1982
1983
1984
1985
1 2 3 4
CRITICAL DESIGN REVIEW
ST SYSTEM REVIEW
SCIENTIFIC INSTRUMENTS
SOLAR ARRAY
OPTICAL TELESCOPE
ST DELIVERY
SUPPORT SYSTEMS MODULE (SSM)
DESIGN
FABRICATION AND ASSEMBLY
SSM ASSY
SSM TEST
SPACE TELESCOPE (ST) ASSEMBLY AND VERIFICATION
ST ASSY AND TEST
SHIPPING AND LAUNCH BASE PREPS
ORBITAL VERIFICATION

Figure 3

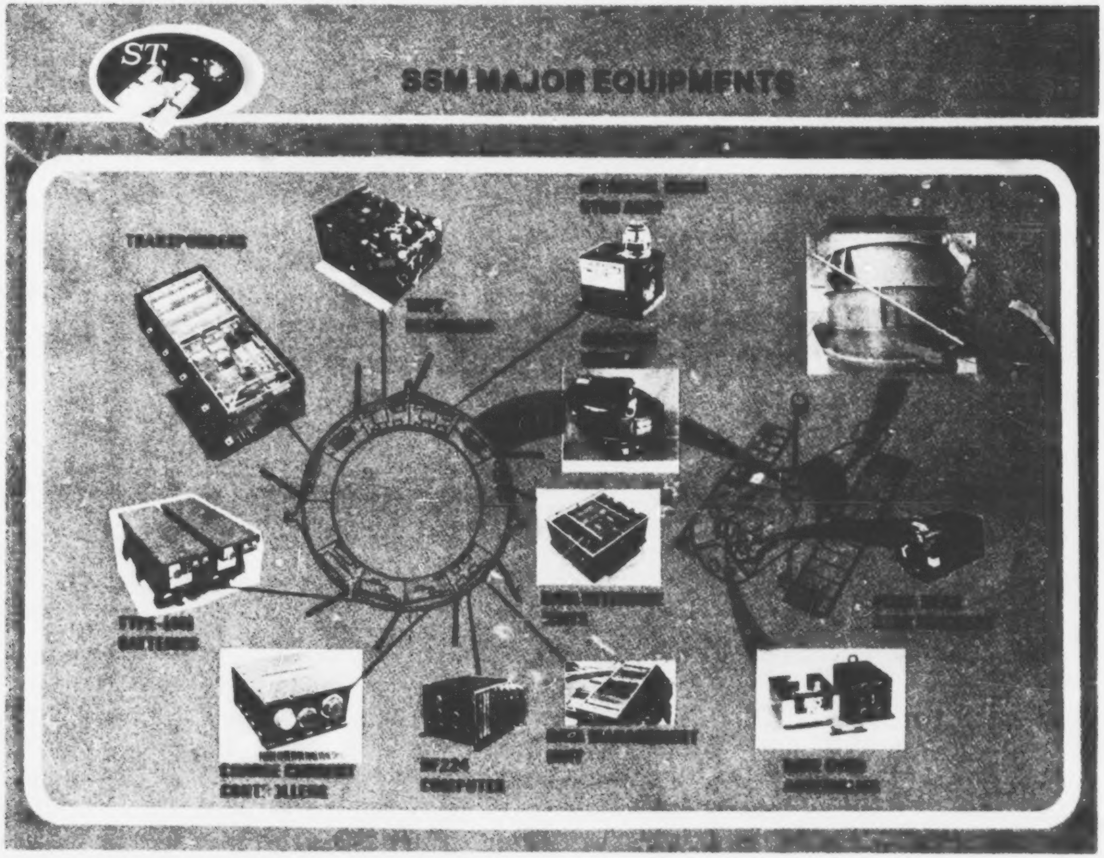


ST SYSTEMS REVIEW
DIGITAL INTERFACE UNIT DELIVERED TO PERKIN-ELMER
SSM/ST TEST PLAN COMPLETE
FLIGHT ROTARY DRIVES DELIVERED
FLIGHT TRANSPONDERS DELIVERED
SOFTWARE DEV LAB COMPLETE
FLIGHT COMPUTER DELIVERED
INTERFACE CONTROL DOCUMENTS BASELINED
ST SOFTWARE REQMTS COMPLETE
START SHROUDED GYRO DEVELOPMENT
DATA MANAGEMENT UNIT ENG TEST COMPLETE
SSM/ST CDR

Figure 4

noteworthy accomplishment is that all the Interface Control Documents for all the modules in the ST, as well as all elements of the systems, have been baselined and are now under configuration control by NASA/MSFC. Of special significance was the initiation of an improved gyro by incorporating a shroud in the gyro which assures the overall ST pointing requirements and stability will be met. The engineering performance verification of a flight prototype consisting of functional environmental tests has been completed, which verifies this improved performance. A major milestone in our software development was accomplished during this period by completing our laboratory testing utilizing key SSM pointing and data management components, and mass simulation of the ST structure. The basic software approach, data management interfaces, and pointing control algorithms necessary for the flight software development were validated under simulated flight conditions on the large Lockheed air bearing table. A key part of our data management subsystem is the Data Management Unit which interfaces the computer to the rest of the ST. This is a rather large, complex electronic unit built by Lockheed. The successful completion of the development testing is of significance, proving the basic coherence of our data management concept. The initial delivery of flight hardware was accomplished during this period; all of these are subcontract hardware, and are similar to hardware utilized by other Lockheed programs.

The Support System Module (SSM) major equipment hardware is shown in Figure 5 illustrating the location of hardware within the SSM equipment section. The SSM is divided into four major sections; namely, the Light Shield which provides stray light protection for the OTA, the Forward Shell which is also light-tight and supports the solar array, high gain antenna mounting, and carries the trunnion fittings which interface with the Shuttle Orbiter. The Equipment Section houses most of the basic data management equipment, electrical power control equipment, certain pointing control equipment and instrumentation and communication electronics which are shown in the figure. The Fixed Head Star Trackers and Rate Gyro Assembly, critical components of the pointing and control system, are mounted on the Focal Plane to assure overall accuracy, and are also shown. The light-tight Aft Shroud, with its access doors for SI orbital replacement capability, also provides the thermal protection for the



SSM MAJOR EQUIPMENTS

ST
TRANSPONDERS
BATTERIES
DF224
COMPUTER
UNIT

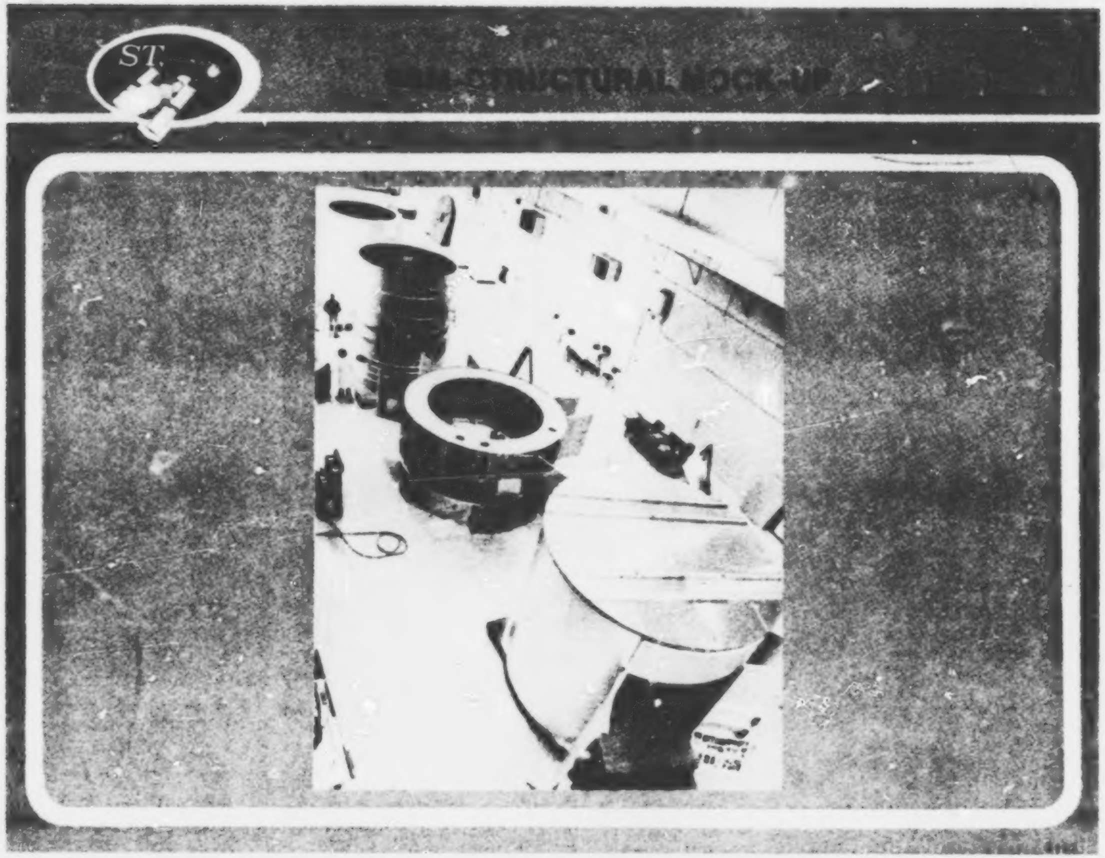
Figure 5

scientific instruments and provides thermal stability and isolation with the OTA. It also provides the structural fittings for erecting the ST while in the Orbiter bay. All of these equipments are either flight equipment already delivered or flight prototype engineering models utilized for qualification and verification of the design. The flight equipments already delivered are the Computer from Rockwell International, Rotary Drives from Schaeffer Magnetics, and the Transponders from Motorola. All remaining electronic flight equipments will be delivered by August 1983.

Figure 6 shows the four major structural segments of the SSM which were utilized early in the program for acoustic testing to simulate the environment of the Shuttle and its effect on the design of the equipment and their installation as well as being utilized for Shuttle crew interface with our orbital replacement units. This structural replica of the ST has been updated and will now be utilized as a low cost manufacturing tool for fabricating all of the ST wire harnesses, utilizing mockups of all the electrical and electronic equipments.

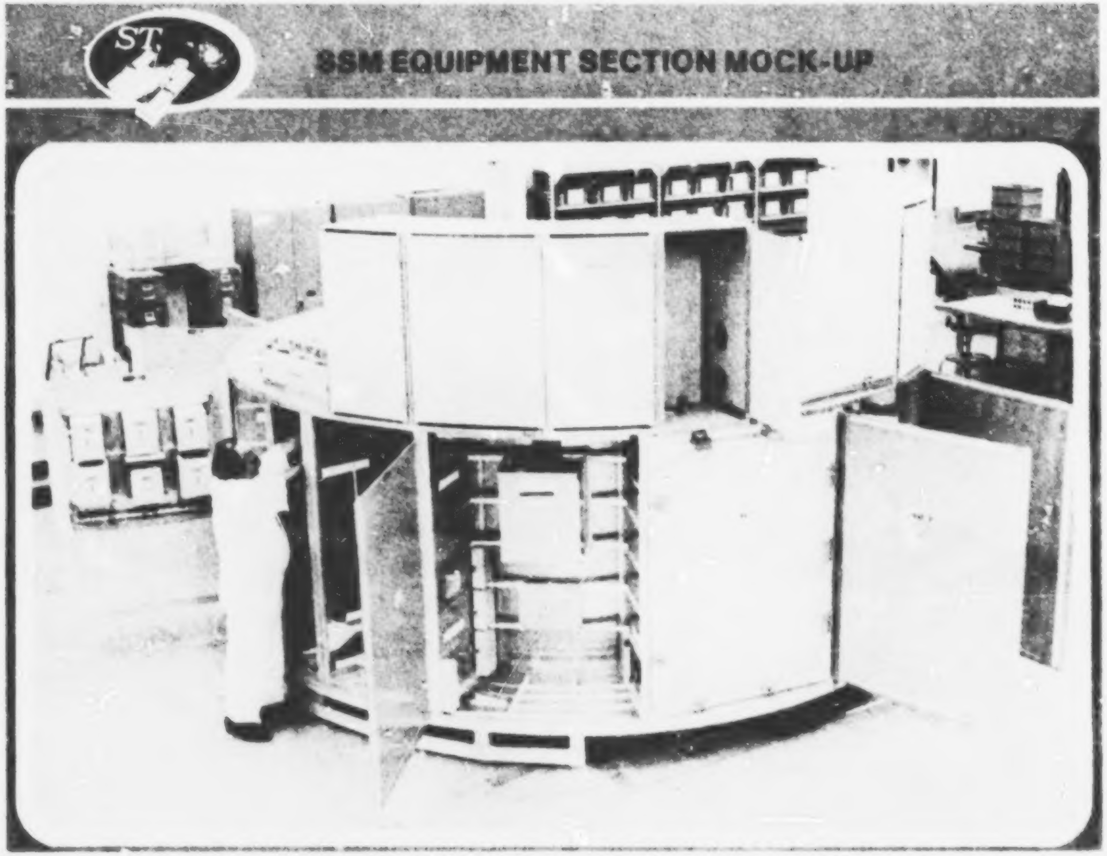
Figure 7 shows the SSM Equipment Section of the mockup in more detail depicting the equipment mockups that will provide the basis for the electronic cable installations. This approach was conceived by Lockheed and the fabrication of flight wire harnesses provides an extremely low cost alternate to extensive documentation or as an alternate extremely expensive three dimensional form boards that would be required in the fabrication of these very large harnesses which contain over 20,000 wires. This activity has just commenced and is on schedule with estimated completion in February 1983.

The Optical Telescope Assembly Equipment Section which is the first ST major flight structure produced by Lockheed to be delivered to Perkin-Elmer in September 1982 is shown in Figure 8. This is tracking to cost and schedule. This Equipment Section is attached to the SSM Equipment Section and provides space and installation provisions as well as thermal protection for the Perkin-Elmer built electronic hardware. The manufacturing cost for tooling and fabrication have been followed closely in order that this experience can be used to validate our projected cost estimates for the remaining ST structural fabrication.



SSM STRUCTURAL MOCK-UP

Figure 6



SSM EQUIPMENT SECTION MOCK-UP

Figure 7

OPTICAL TELESCOPE ASSEMBLY (OTA) EQUIPMENT SECTION

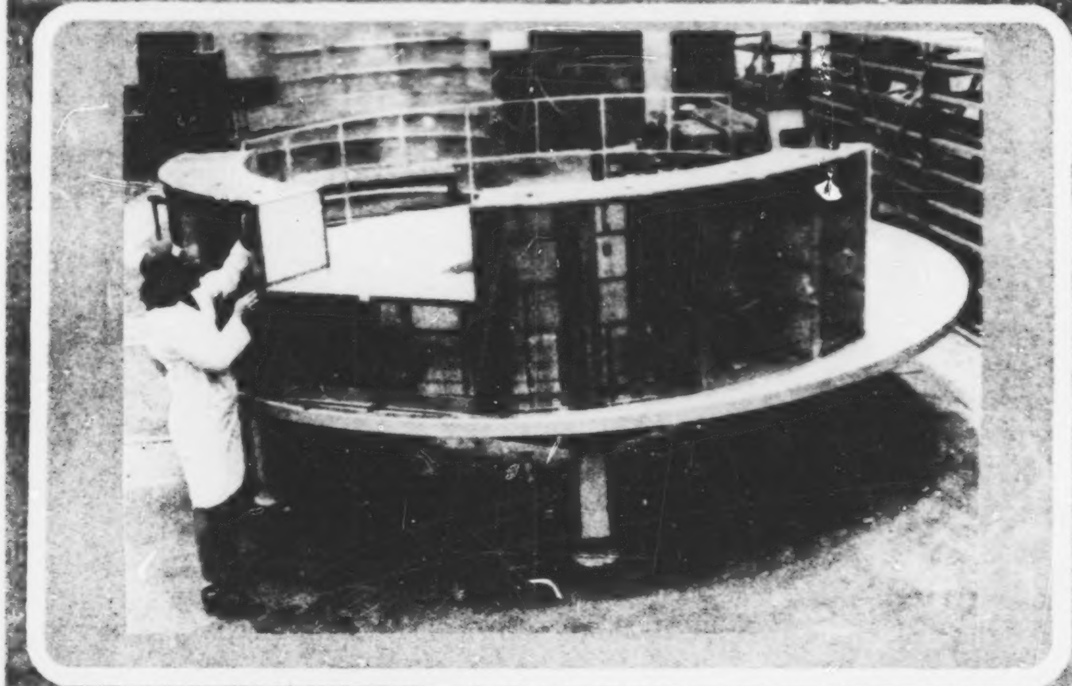


Figure 8

Figure 9 is our Automated Test Software Computer facility. Utilization of this facility continues the Lockheed experience of minimizing system test costs (time) by providing the capabilities to pre-validate all test procedures via simulation before actual testing commences. Also derived from these simulations are predicted spacecraft responses to the test sequences, thus allowing all system parameters to be monitored in real time to pre-established limits. When spacecraft responses are not as predicted, the system allows recovery commands to be entered by the Test Conductor and performs all constraint checks in real time informing the Test Conductor of any violations which require his specific direction to terminate the test or override. The system will handle data rates of up to one million bits per second. Up to 13 user cathode ray tube data display stations are supported with update rates of 1 to 5 seconds. The central computer system consists of two Digital Equipment Corporation computers with standard peripherals which provide for pre-test, real time and post-test processing. The current uses of this facility are: for SSM flight software development and verification, test software development, and engineering data base development. The engineering data base is being delivered on an incremental basis to Goddard for their operations ground system software development. It is the plan that this entire computer complex will be installed in our new ST vertical assembly and test facility shown in Figure 10.

Shown in Figure 10 is a new building constructed and funded by Lockheed which will serve as an SSM and ST final assembly and test facility at our Sunnyvale, California complex. This facility, which will be ready for use at the beginning of next year, is adjacent to our existing environmental test facilities. This new facility consists not only of one of the world's largest horizontal laminar flow cleanrooms for spacecraft integration, but also the necessary support facilities to house support equipment and people. The cleanroom (50 feet wide, 120 feet long and 85 feet high) will be capable of meeting Class 10,000 requirements using a horizontal laminar flow system. A 20-ton radio-controlled bridge crane with a 76 foot hook height will service the 6,000 square foot cleanroom. The contiguous support facility contains 47,000 feet of desk and board and support operations space including 19,000 square feet for the previously mentioned ST Automated Test Software computer system consisting of two Digital Equipment Corporation VAX 11/780 computers and the government supplied command data handling ground test

Figure 9

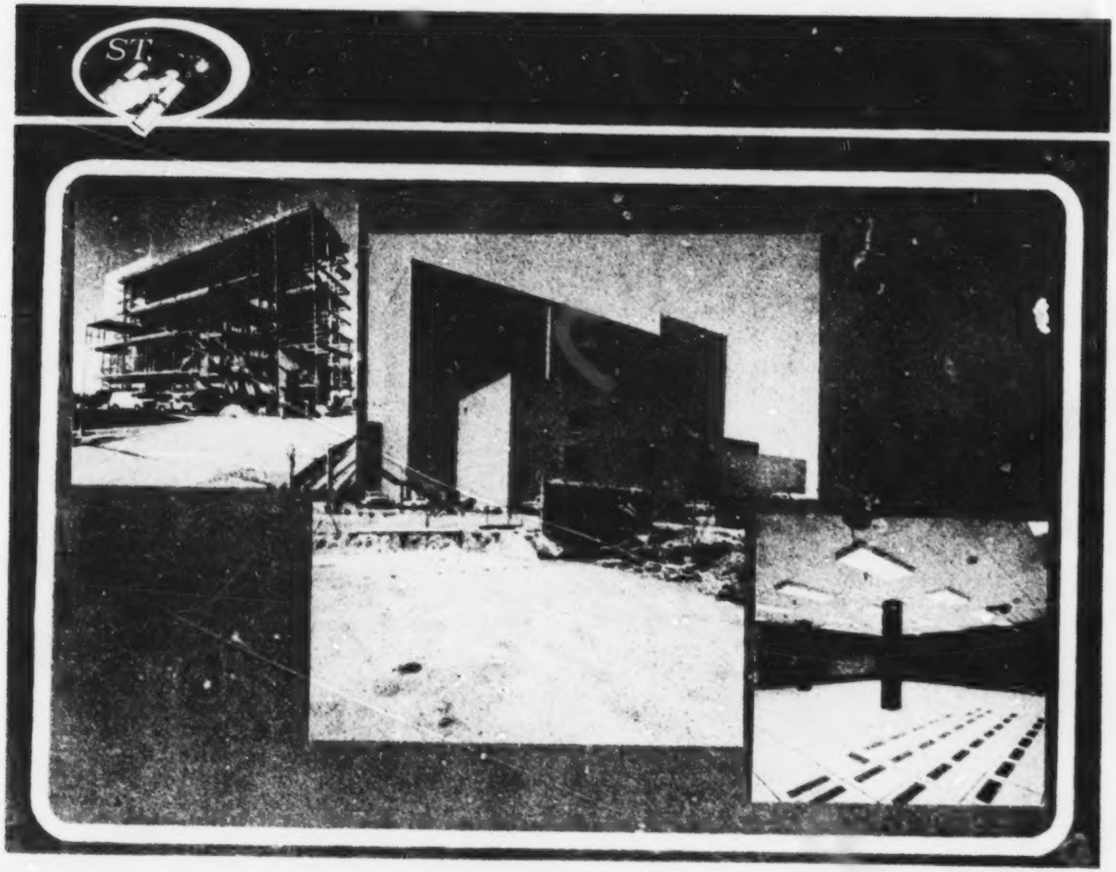
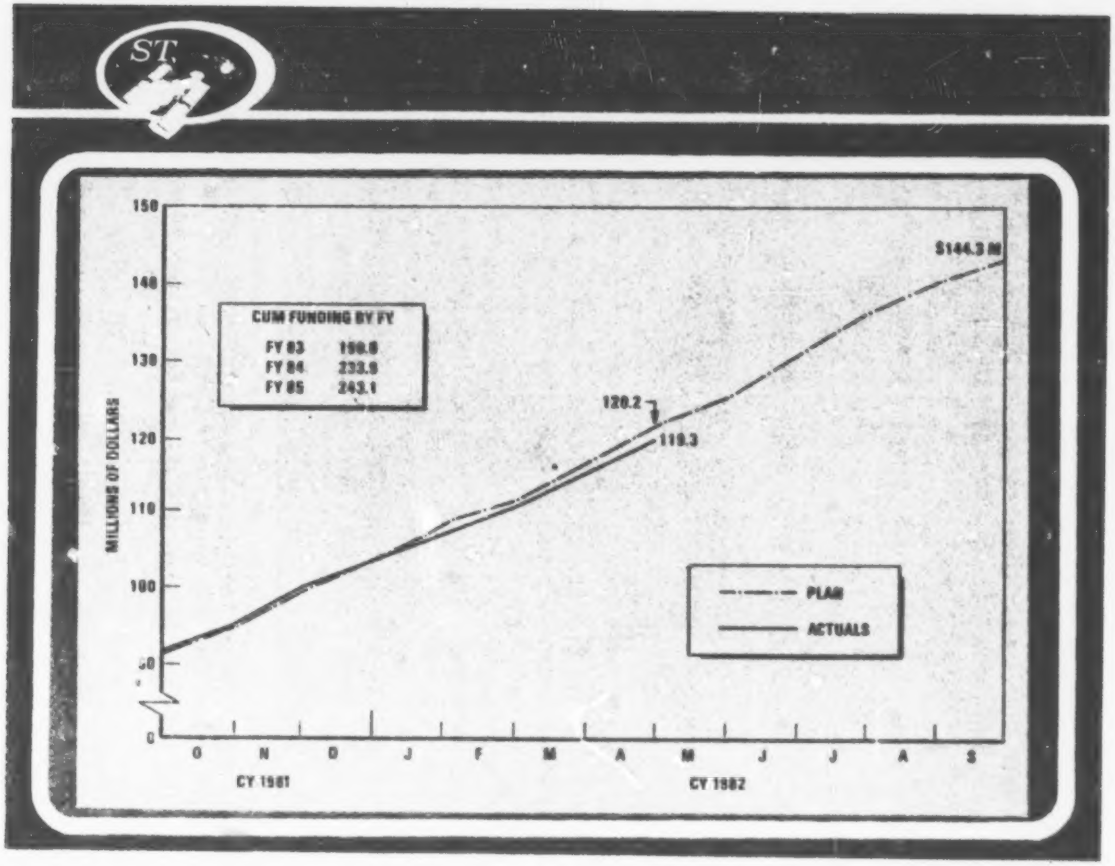


Figure 10

system consisting of a Digital Equipment Corporation 11/70 computer. The new cleanroom opens within the same building housing the spacecraft Vertical Acoustic Test Chamber and the Horizontal Thermal Vacuum Test Chamber.

Figure 11 summarizes our FY 82 cost plan together with the actual expenditures to date. Our costs expended at the present time are $119.3M as compared to our plan of $120.2M. We are in a slightly underrun position to our cost projection; however, late subcontractor billings together with a modest acceleration of our manufacturing build-up should have us right back to our projected figures by mid-June. We are confident that we will meet our funding guidelines for the remainder of this fiscal year. Also shown are our funding requirements for the out years for completion of the program. To summarize, gentlemen, we are on schedule, within our projected costs and we are performing well. We are looking forward to the next phase of the program in completing fabrication of flight hardware, assembling the SSM and conducting ST environmental testing leading to a fully tested ST to be delivered to Kennedy Space Center for integration into the Shuttle in December 1984.


ST
150
140
130
120
110
100
90
0
MILLIONS OF DOLLARS
CUM FUNDING BY FY
FY 83 190.8
FY 84 233.9
FY 85 243.1
120.2
119.3
$144.3 M
PLAN
ACTUALS
O
N
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F
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A
S
CY 1981
CY 1982

Figure 11

Mr. **Flippo**. Thank you, Mr. Wright.

You mentioned the interface documents had been baselined and under the control of Marshall. Under whose control were they before that?

Mr. **Wright**. Prior to the configuration controlled by Marshall, we, the system engineering contractor, had the responsibility of formulating these documents, and then finally approved by both associate contractors involved in each one of those documents. They were then submitted to Marshall for their final approval to assure that they met all of the program requirements—which was a subject of the systems review that I referred to earlier—and then being placed under configuration control by Marshall. Any changes in that document requires their approval together with our recommendation.

Mr. **Flippo**. Have you received any results of Shuttle performance that impacted on this program? For instance, were the vibration tests acceptable?

Mr. **Wright**. We have had updated environmental information as a consequence of the initial flights. We are happy to report that the environmental information we have had so far has had minimum impact on ourselves or the associates.

Mr. **Flippo**. Would Perkin-Elmer care to respond to that?

Mr. **Rehnberg**. Yes. As Mr. Wright has indicated, as the systems integrating contractor for the Space Telescope, Lockheed keeps us apprised changes in the Shuttle loads and have done so since the beginning of the program. We have had to go through some iterative design changes during the course of the program due to some of the Shuttle modifications, but we have not had to make any hardware changes per se.

Mr. **Flippo**. It seems that both Lockheed and Perkin-Elmer have developed some extraordinary facilities or unique equipment in this area. Will those facilities or equipment have further usefulness? How would you use them in the future?

Dr. **Oder**. Certainly ours will, because we are looking forward to building a series of large spacecraft of this kind for which the requirements would be similar. So that is a welcome additional facility for us. We, otherwise, probably would not have seen fit to invest the capital, for its just for a one-time effort.

Mr. **Rehnberg**. Likewise, in Perkin-Elmer's case, we have always been involved in space astronomy programs, going back to the early 1960's, and have invested in capital activities to pursue ventures in this area.

Some of the facilities that have been modified and/or now prepared by Perkin-Elmer for the Space Telescope will be available for future astronomy programs.

Mr. **Flippo**. You may not be able to comment on this, but what is the nature of the spacecraft that you anticipate? Is it in classified areas?

Dr. **Oder**. One would be a program which is called Talon Gold. It is a program which DARPA sponsored and which Lockheed is responsible for. Hopefully, this could be applied to AXAF if we were fortunate enough to be responsible for that. Of course, there is a potential for classified work, but we do handle those currently in an adjoining building.

Mr. **Flippo**. I see.

Would the gentleman from Florida like to ask some questions?

Mr. **Fuqua**. Thank you.

Bill, from the last chart that you showed, it seems you are on time and within budget?

Mr. **Wright**. That is correct. For the past year and a half, our projections, not only for the fiscal years involved but the runout, has been about the same.

Mr. **Fuqua**. What would happen if funds were reduced?

Mr. **Wright**. If the funds were reduced—just to give you a little history with previous testimonies before this committee—Lockheed has been rephased several times, and we had enough flexibility in the schedule to allow us to accommodate these, even though it did increase the overall cost. We are so compressed downstream now—I might add again that, as a result of this rephasing, we are, compared to all associate contractors, last in the progress of fabricating hardware. This was intended, in view of our system engineering responsibility as well as many of the Support Systems Module components being off the shelf; so that we were able to allow our associates greater leadtime and more money in order to maintain their schedule.

So, to answer your question specifically, any cutback in our funds would result in a slip in our schedule.

Mr. **Fuqua**. The reason I asked is because we have under consideration today some budget resolution amendments that would reduce the NASA budget. One of the alternatives of making up that difference would be to delay the telescope for at least a year. About how much would that add in cost? Do you have a ballpark figure?

Mr. **Wright**. Good question. I would hesitate to make an estimate.

Mr. **Fuqua**. I am not trying to pin you down to a figure that you have to live with. I am just asking that for my own edification. Would increase the cost 10 or 20 percent?

Mr. **Wright**. At least 10 percent. I would say approximately $2 million a month just for the Lockheed effort.

Mr. **Fuqua**. $2 million a month increase?

Mr. **Wright**. It depends on where you slip and how it is slipped. When you slip with the marching army, considering all of our test activity, all of our associate contractors involved, and the utilization of that facility, a delay at that time would be very expensive.

Mr. **Flippo**. Dr. Martin might want to comment on that.

Mr. **Martin**. I think a simple way to think about it is, if you look at the funding that we are requesting now for the development, about $121 million in fiscal year 1982, if you stretched it, you would talk about adding to that marching army of activities at about that level. So you could argue that it is around $120 million, assuming you did it efficiently.

But one of the lessons we learned from this last rephasing exercise is that it takes us 6 to 9 months to get our feet on the ground once we go through and start slipping schedules. So I think you better add some serious inefficiencies to the other end of that.

Mr. **Fuqua**. There are proposals to hold NASA funding at the fiscal year 1982 level, which is $670 million below what the administration requested in fiscal year 1983. That is $670 million that NASA would have to absorb. One way would be probably slipping the Shuttle, the fourth Orbiter, other measures. One that was suggested was maybe to slip the Galileo, and also the Space Telescope. So that was the concern that I had, the impact that that would have.

Mr. **Martin**. We are concerned also. Thank you.

Mr. **Fuqua**. Thank you.

Thank you, Mr. Chairman.

Mr. **Flippo**. Thank you.

The gentleman from New York?

Mr. **McGrath**. I have no questions, Mr. Chairman.

Mr. **Flippo**. Gentlemen, we thank you very much for your testimony today. It will be very helpful to us.

I did want to give you an opportunity to comment on any answers that NASA gave us or to elaborate any comments that NASA made here.

If not, we certainly appreciate the effort you have gone to to come and give us the benefit of your views. Thank you very much.

The subcommittee will stand adjourned.

[Whereupon, at 11:08 a.m., the subcommittee was adjourned.]

APPENDIX

NASA

National Aeronautics and
Space Administration

Washington D C
20546

EXCERPT FROM NASA

Reply to Attn of: SAT

18 MAR 1977

AO No. OSS-1-77

ANNOUNCEMENT OF OPPORTUNITY

FOR

SPACE TELESCOPE

I. DESCRIPTION OF OPPORTUNITY

The National Aeronautics and Space Administration (NASA) announces the solicitation of proposals for scientific investigations and related participation in the Space Telescope (ST). This mission is under consideration for launch by the Space Shuttle during the fourth quarter of Calendar Year 1983. While the implementation of the ST Program has not yet been approved by Congress, an early selection of scientific participants will permit a prompt start on scientific planning and related hardware definition, if and when such approval is received. This solicitation does not constitute an obligation on the part of the U.S. Government to carry the proposed effort to completion.

The ST Program is conceived as a long-term program in space astronomy that will provide mankind with an astronomical capability not achievable by any current or foreseeable ground-based telescope. A high-resolution 2.4-meter telescope will be placed in a circular Earth orbit at an altitude of approximately 500 km with an inclination of 28.8° to the equator. The telescope will be an F/24 Ritchey-Chretien design (34% central obscuration diameter ratio) with a focal plane data field ≥ 0.30 m in diameter. It will provide point-source images with 70% energy within a diameter of ≤ 0.2 arc seconds at 633 nm and will have useful sensitivity over the wavelength range 120 nm to 1 mm. Up to five Scientific Instruments (SI's) will be accommodated at the focal plane.

The ST will differ from existing automated satellites in that it will be designed to permit on-orbit maintenance and repair by a space-suited astronaut and be retrievable by the Space Shuttle for return to Earth for refurbishment and subsequent relaunch. A feature of the design will be the provision for replacement of any of the focal-plane SI's at the time of on-orbit visits or during ground refurbishment. This will allow updating of the instrumentation and the use of the ST to fulfill a broad range of scientific requirements over its lifetime, which is expected to exceed a decade. The on-orbit visits and/or refurbishments are nominally scheduled for 30-month intervals; however, the exact timing will depend on the operating efficiency and scientific program of the ST.

The overall ST Project is being managed by Marshall Space Flight Center (MSFC). Goddard Space Flight Center (GSFC) is responsible for managing the development of the SI's and for post-launch operation of the observatory.

This Announcement of Opportunity (AO) is a solicitation of proposals for scientific investigations and the definition and development of focal-plane SI's required to carry out the investigations and for individual "Observatory Scientists" who will be selected to perform scientific investigations using the initial complement of focal-plane SI's and to assist the ST Project in working out scientific mission parameters, as delineated later in this AO. One of the initial focal-plane SI's, a Faint Object Camera (FOC), will be provided by the European Space Agency (ESA), subject to satisfactory negotiation of a formal agreement between NASA and ESA.

Scientists selected through this AO and who participate substantially in the development of the ST and its initial focal-plane SI's will be allocated observing time in the early months of operation.

Specifically, proposals are now solicited from:

A. Investigation Definition Teams (IDT's), each consisting of a Principal Investigator (PI) and appropriate Co-Investigators (Co-I's) proposing a scientific investigation and the definition and development of focal-plane instrumentation required to carry out that scientific investigation;

B. Individual investigators who desire consideration as a Co-I on an IDT (including U.S. representation on the ESA FOC Team); and,

C. Individual investigators who desire to participate as Observatory Scientists.

For a more detailed description of all categories of participation, see Section V.A.

The PI's, Observatory Scientists, and appropriate NASA and ESA scientists will constitute an ST Science Working Group, chaired by the NASA Project Scientist. This Working Group will assist the ST Project in working out scientific mission parameters.

II. MISSION OBJECTIVES

Scientific Objectives

The scientific objectives of the ST are to determine:

A. The constitution, physical characteristics, and dynamics of celestial entities;

B. The nature of processes which occur in the extreme physical conditions existing in and between astronomical objects;

C. The history and evolution of the universe; and,

D. Whether the laws of nature are universal in the space-time continuum.

The ST will increase the sensitivity and resolving power and extend the spectral range of astronomical observations decisively beyond those achievable from ground-based observatories. While it is likely that the ST will reveal unimagined phenomena and, hence, will open new areas of scientific inquiry, the following are examples of the type of specific scientific objectives, within the broader objectives above, which have been suggested. (These specific objectives are not intended to limit the scope of scientific programs which may be proposed by respondents to this AO. However, to be considered for selection, proposals must be within the scope of the scientific objectives of the ST, as stated above.)

BEST DOCUMENT AVAILABLE

- Precise determination of distances to galaxies out to expansion velocities $\sim 10^4$ km s^{-1} and calibration of distance criteria applicable at cosmologically significant distances
- Determination of the rate of the deceleration of the Hubble expansion of the universe, its uniformity in different directions, and possibly its constancy with time
- Testing of the basic reality of the universal expansion by determination of the surface brightness versus red shift relation for distant galaxies
- Establishment of the history of star formation and nuclear processing of matter as a function of position in nearby galaxies and determination of the variations from galaxy to galaxy
- Determination of the nature of stellar populations in the early stages of galactic evolution, based on "lookback" observations of distant galaxies
- Estimation of the He/H ratio in quasars by observation of red-shifted He I and He II resonance lines
- Search for multiple-red-shift absorption line groups in the ultraviolet spectra of low-red-shift quasars
- Intercomparison of total spectra of high-red-shift quasars, low-red-shift quasars, and active galactic nuclei
- Resolution of densely-packed nuclei of globular star clusters in search of massive black holes
- Identification and flux measurement in ultraviolet and optical wavelengths of faint x-ray sources and radio pulsars
- Resolution of the complex internal structure of Herbig-Haro objects to investigate their possible links to star formation

- High spatial resolution, infrared observations of proto-stars
- Direct imaging and astrometric search for planetary companions of nearby stars
- Determination of bolometric luminosities of faint, hot stars for studies of stellar evolution
- Determination of composition, temperature, density, and ionization structure of the gas in the galactic halo, in high-velocity clouds, and in the intergalactic medium
- Precise mapping of the 100 μm flux sources in compact H II regions
- Determination of composition of clouds in the atmospheres of Jupiter, Saturn, Uranus, and Neptune
- Surface mapping of the Galilean satellites of Jupiter and of asteroids
- Synoptic mapping of atmospheric features on Venus, Jupiter, Saturn, and Uranus
- Intensity measurements of atomic and molecular ultraviolet emission lines important to understanding the chemistry of comets

III. SPECIFIC REQUIREMENTS AND CONSTRAINTS ON INVESTIGATION DEFINITION TEAM (IDT) PROPOSALS

The ST and its SI's will be designed and developed within the framework of a tightly cost-controlled program, leading to the proposed launch in the fourth quarter of 1983. The SI's will be delivered to GSFC 28 months prior to launch for NASA acceptance testing and verification. The number and amount of associated development of instruments required for investigations selected for the first mission will be limited by the total funding available in the program budget. It is imperative that proposers estaolish a credible low-cost approach and schedule for the development of flight-quality instruments and associated hardware.

Initial IDT selections will be tentative. Following tentative selection, each PI will be funded to carry out a preliminary design study, including breadboarding or other activities necessary to verify the detailed approach and costs for the final instrument development phase. At the end of this initial activity, the PI (if responsible for instrument development)will submit an updated implementation plan and schedule for the instrument development. NASA will then reevaluate the scientific, technological, and cost aspects of each instrument. Based on this reevaluation, the NASA Associate Administrator for Space Science will confirm the participation as originally determined, direct modifications to meet Project schedule and funding limitations, or terminate the proposed participation. At that time, firm commitments to performance specifications, costs, schedule, and scope will be established for each instrument development to be completed. Contracts for participation in the operations phase of the Project and for the timely deposit of the resulting data in the National Space Science Data Center will be negotiated later.

Preliminary studies have been carried out for the types of instruments listed below. Final reports on these studies, as well as on separate studies of various detectors appropriate for use in the instruments, are available by use of the attached order form (Attachment M).

A. Ultraviolet Spectrographs

   1. Faint Object Spectrograph (FOS)
   2. High Resolution Spectrograph (HRS)
   3. Combined FOS-HRS

B. High Resolution Cameras

   1. Wide Field Camera (WFC)
   2. Faint Object Camera (FOC) (to be provided by ESA)
   3. Planetary Camera (PC)

C. Photometers

   1. Infrared Photometer (IRP)
   2. High-Speed Photometer (HSP)

D. Guidance System (Astrometry)

NASA has determined that, for reasons of cost-effectiveness, astrometry will be carried out with the spacecraft guidance system and no separate SI will be developed for astrometry. NASA will, however, select a scientific investigation in this area involving a PI and possibly several team members.

Also, NASA (with the advice of the astronomical community) has designated the WFC and the FOS as particularly important. If qualified proposals for investigations involving these instruments are received, a WFC and an FOS will be selected for inclusion in the initial instrument complement. Qualified proposals are those for investigations which are considered to be well conceived, scientifically and technically sound, and pertinent to the goals and objectives of the ST Program. In addition, they must be offered by a competent investigator from an institution capable of supplying the necessary technical and management capabilities to ensure that flight hardware or other support can be delivered on time and within budget and that data can be properly reduced, analyzed, interpreted, and published in a reasonable time. Finally, qualified proposals are those recommended, with high priority, for tentative selection.

Proposals may be submitted for investigations responsive to the stated objectives of this AO and entailing the design, development, and scientific application of any suitable instrument (excepting an FOC or astrometry instrument), whether or not it was previously studied. The proposer must establish the scientific merit, technical feasibility, interface compatibility, consistency of the effort with the proposed budget and schedule, and the existence of wide interest within the scientific community.

A working description of the FOC to be provided by ESA is contained in the attached summary of scientific instrument performance goals (Attachment H).

IV. ALLOCATION OF OBSERVING TIME

Those scientists selected for participation in the ST Program as a result of this solicitation will be involved in the development of the ST and its initial complement of instruments. After launch, they will be involved in the on-orbit checkout expected to last about one month, after which the ST will be declared operational.

As has been the custom for ground-based telescopes, observing time will be assigned primarily on the basis of the scientific merit of competitive observational proposals. During the first 30 months after the ST is declared operational, a portion of the observing time will be allocated to the IDT's, the Astrometry Team, and the Observatory Scientists selected as a result of this solicitation. The remainder of the observing time until the first on-orbit maintenance will be available for the general ST Observer Program which will be the subject of subsequent AO's, the first of which will be issued about nine months before the initial launch. Scientists selected now will be free to compete for this additional time.

The monthly percentages of the total observing time, which will be allocated to the IDT's, the Astrometry Team, and Observatory Scientists, are as follows:

Period	% Allocated
Months 1-2 (after checkout period)	100%
Months 3-8	50%
Months 9-20	25%
Months 21-30	10%

In dividing the above time allocations among the various participants, the Observatory Scientists, as a group, will be treated in the same manner as a single IDT or Astrometry Team. The U.S. member(s) chosen for the ESA FOC Team will be allocated time comparable to that allocated to Co-I's on U.S. IDT's. While the IDT's will have priority on the use of their own instrument during this allocated time, they may negotiate observing time on other SI's which may be required to complement their own investigations.

NASA is considering the establishment of an ST science operations facility which would manage the scientific use of the ST during its operational life. Observing time for all observers, including those selected by this and subsequent AO's, would be scheduled by this operations facility. PI's will have an ongoing responsibility during the period after post-launch checkout to assist in the operation, calibration, data processing associated with their instruments and to assist other observers in the use of their instruments.

V. EVALUATION AND SELECTION PROCESS

A. Categories of Participation

1. Investigation Definition Teams (IDT's)

Proposals are solicited for scientific investigations and for definition and development of scientific focal-plane instruments for the ST required to carry out the investigations. In addition to a complete description of the scientific investigation, proposals should cover the development of the entire required instrument, including detectors. The proposing Team should consist of a PI and the Co-I's necessary to complete the proposed investigation. NASA may elect to delete members from a proposed Team and/or augment the membership of Teams with selected scientists who have proposed individually or as part of other Teams.

Team proposals headed by a PI are invited also for astrometric investigations. The selected Astrometry Team will not design or develop hardware but, in addition to the pursuit of its investigation, will assist the ST Project in the definition of the guidance system to insure that it will perform satisfactorily for astrometry within budget, operational, and schedule constraints. The Team will also develop the software required for reducing the astrometry data, and will implement the astrometric science program.

2. Individual Investigators

Proposals are invited from individual scientists not allied with a proposing Team who wish to propose scientific investigations which may impact the design of a particular instrument or who are interested in the astrometric use of the fine guidance system. NASA may select such individual scientists as PI's or as additional Co-I's on IDT's. U.S. scientists interested in performing investigations with the FOC and participating on the ESA FOC Team should also propose as individuals. It should be noted that the one or more U.S. members of the FOC Team will need to travel extensively. Individual instrumentalists, e.g., detector specialists, are encouraged to affiliate with more than one IDT proposal. Separate detector proposals should not be submitted to NASA in response to this AO.

3. Observatory Scientists

Proposals are invited from scientists wishing to serve in one of the following capacities: Telescope Scientists, Interdisciplinary Scientists, and Data and Operations Team Leader.

Telescope Scientists will carry out scientific investigations and will assist the ST Project to assure that the spacecraft is compatible with scientific requirements. In addition to proposing a qualified scientific investigation for the ST, individuals proposing as Telescope Scientists should have a broad knowledge of imaging optical systems, with a working knowledge of the relation of optical and thermal mechanical systems and their effects on the performance of the observatory.

Interdisciplinary Scientists are generalists or theoreticians who, in addition to carrying out scientific investigations using the ST, will serve the Project by maintaining a broad and critical scientific overview of the ST development. Proposers as Interdisciplinary Scientists should not only propose qualified specific scientific investigations using the ST but should also have a thorough knowledge of the forefront problems of modern astronomy and astrophysics and a clear interest in applying the capabilities of the ST to those problems. Moreover, these scientists must be able to relate the potential attainment of general scientific goals to specific characteristics of the ST and SI performance.

The Data and Operations Teams Leader will carry out scientific investigations and will assist the Project to assure that the SI Control and Data Handling System is consistent with scientific requirements. He will head a Team consisting of a representative from each of the IDT's, which will assist in developing the detailed requirements for the SI Control and Data Handling System and in providing integrated SI operations and data management requirements. Proposers for the Data and Operations Team Leader, in addition to proposing a qualified scientific investigation for the ST, should have a good understanding of instrument and control systems, flight operation, and ground data handling systems.

B. Evaluation of Proposals

Proposals received in response to this AO will be evaluated in accordance with the provisions of NASA NHB 8030.6 - Guidelines for Acquisition of Investigations. Accordingly, such proposals will be reviewed by a group of peers of the proposers, appointed by the NASA Associate Administrator for Space Science. The purpose of the review is to assess the scientific merit of the proposals in the context of this AO. Those proposals involving flight hardware which are considered to have the greatest scientific merit will be reviewed further by GSFC and MSFC for the following:

- 0 Soundness of engineering
- 0 Compatibility with the spacecraft
- 0 Management approach (including schedule and cost)
- 0 Safety aspects

The NASA Associate Administrator for Space Science will make his selections on the basis of these reviews and those of appropriate NASA Headquarters Offices.

C. General Criteria Used in All Selections

The identification of ideas and unique capabilities which best suit the overall scientific and technological objectives of the Program is a fundamental aim of the investigation acquisition process. Hence, the following general criteria will be used in all selections:

- 0 The relevance to the unique capabilities of the ST
- 0 The scientific and technological merit of the investigation, including the desirability of the investigation within the discipline to which it pertains and the probability of acquiring positive results
- 0 The competence and relevant experience of the investigator or PI and his team as an indication of his ability to carry his investigation to a successful conclusion

- The adequacy of whatever apparatus may be proposed with particular regard to its ability to supply the data needed for the investigation

- The reputation and interest of the proposer's institution, especially from the viewpoint of whether the institution will provide necessary support to insure that the investigation can be completed satisfactorily

- Cost and management factors

D. Specific Criteria

1. Investigation Definition Teams (IDT's)

In addition to the general criteria listed above, the following specific criteria will be applied for judging IDT proposals. The criteria are in the general order of their significance:

- The adequacy of proposed instrument hardware with particular regard to its capability of yielding the data required for the investigation

- Compatibility of the instrument with observatory hardware and functional interfaces

- Current state of development of the proposed instrumentation hardware and design

- General usefulness of the proposed instrument for other investigations

- The cost necessary to bring the investigation to a satisfactory completion

- The ability of the PI to meet major Project milestones and hardware delivery dates

- Simplicity of approach

- The contribution to the Team by each member

- The adherence to good management practices as exhibited in the management plan

2. Individual Investigators and Observatory Scientists

The general criteria will apply to proposals for individual investigators and Observatory Scientists. Specific consideration will be given to the demonstrated competence of the proposer to fulfill the specific responsibilities of the role proposed. The evaluation will consider the commitment of the proposer as evidenced by the amount of time he plans to devote to this Project and the extent to which he can be available on specific dates as needed by the Project.

IV. PREPROPOSAL ACTIVITIES

A. Preproposal Briefings

A sequence of three preproposal briefings will be held at the following locations:

DATE: Monday, April 11, 1977

TIME: 1 - 4 p.m.

PLACE: Building 3 Auditorium
NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771 USA

DATE: Tuesday, April 12, 1977

TIME: 9 - 12 a.m.

PLACE: Conference Room - First Floor
Laboratory for Astrophysics & Space Research
University of Chicago
933 East 56th Street
Chicago, Illinois 60637 USA

DATE: Thursday, April 14, 1977

TIME: 9 - 12 a.m.

PLACE: Baxter Lecture Hall
California Institute of Technology
Pasadena, California 91125 USA

The agenda for each briefing will be:

1. The Management Plan for the ST Program
2. The design characteristics of the ST
    - The Optical Telescope Assembly
    - System stability and operations
    - Characteristics of the principal focal plane
    - Constraints on SI designs
3. Results of previous studies of SI's and detectors
4. Organization of instrument development effort
5. Financial constraints
6. Review of proposal preparation instructions

Proposers are encouraged to attend one of these briefings prior to submitting a proposal. Although reservations are not required, it is requested that notification of intent to attend a briefing be sent to:

Dr. C. R. O'Dell
ST Project Scientist, DS-30
NASA/Marshall Space Flight Center
Alabama 35812 USA

with a copy to:

Dr. D. S. Leckrone
Instrument Scientist, Code 671
NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771 USA

Questions on any aspect of this solicitation and requests for technical information may be addressed to Dr. O'Dell or Dr. Leckrone.

A copy of any request for information by European scientists should be addressed to the ESA Head Office, Department of Future Scientific Programmes, which will then arrange, if necessary, for Dr. Leckrone to meet the European astronomers at a date and place to be jointly agreed.

B. Letters of Intent to Propose

Investigators wishing to propose as a result of this solicitation should submit a Letter of Intent (two-page maximum) to be received on or before April 26, 1977, at the following address:

Dr. Nancy G. Roman
ST Program Scientist (AO-OSS-1-77)
Astrophysics Programs, Code SA
NASA Headquarters
Washington, D.C. 20546 USA

The Letter of Intent should include the proposer's name, address, and telephone number; the name of his sponsoring organization; and, a list of his Co-I's, if any, with their respective institutions. The investigator should state the category in which he will propose and a brief summary of his specific objectives. Material in these Letters of Intent is for information only and is not binding on the signatories. On receipt of a Letter of Intent, NASA will provide the supplemental information requested by the proposer using the attached order form (Attachment M).

VII. FORMAT OF PROPOSALS

A uniform proposal format (including cost proposals for U.S. investigators) will be required to aid in proposal evaluation and to facilitate comparative analysis. Details of the format are contained in the proposal preparation information attached to this AO (Attachments C, D, and E).

VIII. PROPOSAL SCHEDULE

Letter of Intent due not later than	April 26, 1977
Preproposal Briefings	April 1977

Proposals due

- U.S. scientist endorsed copy	July 11, 1977
- Non-U.S. scientist advance copies	July 11, 1977
- Non-U.S. scientist endorsed copy	August 11, 1977
Selection (tentative for IDT's)	October 1977
Complete Preliminary Design of SI's	October 1978

Proposals for participation will be required by close of business (4:30 p.m., EDT) on the dates specified above. The proposal must conform to the attached instructions. Thirty (30) copies of each proposal, including the endorsed copy, should be sent to Dr. Roman at the above address.

IX. FOREIGN PROPOSALS

Proposals for participation by individuals outside the United States should be submitted in the same format (excluding cost plans) as U.S. proposals. They should be typewritten and in English.

Foreign proposers must have their proposal reviewed and endorsed by the appropriate foreign governmental agency. Endorsed proposals should be forwarded to NASA in order to arrive before the deadline indicated under Section VIII, "Proposal Schedule." Letters of Intent to propose and 30 advance copies of the proposal should be sent directly to Dr. Roman at the above address, with a copy to be sent to:

National Aeronautics and Space Administration
Office of International Affairs, Code I
(Ref: AO-OSS-1-77)
Washington, D.C. 20546 USA

All other correspondence (including endorsed proposals) from foreign proposers and organizations should be sent to NASA's Office of International Affairs.

In addition, proposers from ESA member countries should send an information copy of both the Letter of Intent and the proposal to the Department of Scientific Programmes of ESA at the following address:

Dr. V. Manno
Department of Scientific Programmes
European Space Agency
8-10 Rue Mario Nikis
75738 Paris Cedex 15, France

Dr. Manno may also be contacted for further information about proposal submission.

Foreign proposals will go through the same evaluation and selection process as U.S.-originated proposals. Should a proposal be selected, NASA will arrange with the sponsoring foreign agency for the proposed participation on a cooperative (no-exchange-of-funds) basis, in which NASA and the sponsoring agency will each bear the cost of discharging its respective responsibilities.

X. PROPOSAL PREPARATION INFORMATION

A summary of the proposal preparation information attached to this AO and the required response information is provided in Table 1, "Relevant Attachments and Response Requirements for each Category of Participation."

Noel W. Hinners

Noel W. Hinners
Associate Administrator
for Space Science

Attachments

APPLICABLE ATTACHMENT / CATEGORY OF PARTICIPATION	INVESTIGATION DEFINITION TEAM (INCLUDING PI)	CO-INVESTIGATORS	ASTROMETRY TEAM	DATA AND OPERATIONS TEAM LEADER	U.S. MEMBER OF ESA FOC INSTRUMENT SCIENCE TEAM	TELESCOPE SCIENTIST	INTERDISCIPLINARY SCIENTIST
A. GENERAL INSTRUCTIONS AND PROVISIONS	x	x	x	x	x	x	x
B. SI'S MANAGEMENT PLAN	x	x	x	x	x	x	x
C. SI SUMMARY SECTION OUTLINE	x						
D. GUIDELINES FOR PREPARATION OF THE PI'S TECHNICAL AND MANAGEMENT/COST PROPOSALS	x						
E. RESPONSIBILITIES AND PROPOSAL GUIDELINES FOR THE ASTROMETRY PI (AND HIS TEAM), SCIENTIFIC CO-I'S, U.S. MEMBERS ON ESA FOC INSTRUMENT SCIENCE TEAM, AND OBSERVATORY SCIENTISTS		x	x	x	x	x	x
F. ST INTERFACE REQUIREMENTS FOR SI TO OTA AND SSM	x	x		x			
G. PROJECTED ST IMAGE QUALITY	x	x	x	x	x	x	x
H. SUMMARY OF SI PERFORMANCE GOALS FOR THE ST	x	x	x	x	x	x	x
I. ON-BOARD OPERATION OF SI'S IN THE ST	x	x		x	x		
J. SUMMARY IMPLEMENTATION PLAN FOR SI QUALIFICATION AND ACCEPTANCE PROGRAM	x	x					
K. ST SI FLIGHT ASSURANCE PROGRAM	x						
L. FLIGHT OPERATIONS AND SCIENCE DATA PROCESSING	x	x	x	x	x		
M. ST SI DOCUMENTATION ORDER FORM	x	x	x	x	x	x	x
RESPONSE REQUIREMENTS							
. LETTER OF INTENT	x	x	x	x	x	x	x
. SI SUMMARY SECTION	x						
. TECHNICAL PROPOSAL	x	x	x	x	x	x	x
. MANAGEMENT/COST PROPOSAL	x						
. COST PROPOSAL		x	x	x	x	x	x

RELEVANT ATTACHMENTS AND RESPONSE REQUIREMENTS
FOR EACH CATEGORY OF PARTICIPATION

TABLE 1

NAS5-26555
SOW
April 15, 1981

STATEMENT OF WORK (SOW)
FOR THE
SPACE TELESCOPE SCIENCE INSTITUTE (ST ScI)

1.0 INTRODUCTION

This Statement of Work (SOW) defines the work effort required to establish, operate, and maintain a Space Telescope Science Institute (ST ScI). Within broad policy generated by NASA, the ST ScI will conduct the science program of the Space Telescope (ST), in such a way as to maximize the scientific usefulness of this major spaceborne observatory. It is believed that this approach will best bring the user community into direct contact with and control of the science that is done.

The ST ScI will perform many necessary functions. It will establish ST science program guidelines. It will select ST observers and archival researchers, fund US user participation, and provide direct technical support to observers before, during, and after their observations. It will develop an integrated observing schedule to be used by the operations control center. It will sponsor ST related research necessary for efficient use of the observatory. It will evaluate the scientific performance of the ST observatory and its individual Scientific Instruments (SIs), and advise NASA on observatory status. It will process, archive, and publicize the scientific data derived with the ST, making this information accessible. It will conduct a program to encourage visiting scientists. It will establish a scientific staff of the first rank to perform the above functions and conduct their own research related to the ST.

1.1 NATURE OF THE SPACE TELESCOPE

1.1.1 Optical Properties

The ST will be a Ritchey-Chretien Cassegrain instrument of 2.4 meters diameter. It will have the best optical performance compatible with project cost and is expected to significantly surpass all existing ground based telescopes. It will have point source spatial resolution of 0.1 arc seconds and, in particular, image energy concentration will be such that 70 percent of the total energy will be enclosed by a circle of 0.2 arc seconds diameter. This performance is measured at 6328 A and is the minimum quality specified in the telescope contract. There is the possibility of better performance at shorter wavelengths, down to a yet-to-be-determined optimum wavelength, and better performance at 6328 A if the minimum specifications in the contract are surpassed.

The useful Field Of View (FOV) has been divided into eight portions. The outer three, in an annular ring surrounding the central FOV, are used by the Fine Guidance System (FGS), which provides the signal for the precise tracking of the ST. The remaining five portions, in the central portion of the FOV, are used to feed the individual SIs; one (in the radial bay) receives its light by means of an on-axis diverting flat, while the others (in four axial bays) are directly illuminated at the Cassegrain focal surface. This sharing of the optical image provides obvious potential for simultaneous use of some SIs. In addition, there are certain electrical, thermal, power, and data handling constraints that must be observed.

The ST has a wavelength operating range from about 1150 Å (where MgF_2 overcoatings on the mirrors drastically reduce transmission) out into the millimeter wavelengths. The first complement of flight instruments does not exploit this entire range; however, venting capabilities are being provided for possible future cryogenically cooled infrared SIs.

1.1.2 Pointing and Stability

The ST obtains its pointing information from four sources: fixed head star trackers viewing in directions orthogonal to the optical axis; gyroscopes; the FGS, the SIs. These sources of information are appropriately utilized during the acquisition of an object according to the precision with which the desired position is known and the accuracy required. The requirement is not simply to point the SI aperture at the correct object, but also for the FGS to acquire an appropriate pair of guide stars. Three modes of acquisition are possible. Mode III simply points the ST based on positions of the object and guide stars which have been determined with adequate precision on the ground. This mode will be used most often by the cameras with their wide fields of view. Mode II starts with Mode III, but then uses a signal from within the relevant SI to provide "peak up" commands to the telescope in an automatic mode. This mode will find its largest use in centering objects in simple fields into small apertures, such as are used in spectrographs. Mode I also begins with Mode III, but provides information from the relevant SI to the ground scientists and controllers who then decide what "peak up" adjustments should be made. Since this mode is subject to the most operational constraints and inefficiencies of use of time, it is expected to be used for only a small fraction of the acquisitions.

Once the acquisition of the guide stars has been made, ST pointing will remain stable to 0.007 arc seconds (rms). In tracking an object moving with respect to the stellar background, the achieved accuracy will be somewhat lower.

There is always the possibility that adequate guide stars might not exist (i.e., within the FOV of the FGS with respect to the desired target); however, the system is specified so that on the average 85 percent of all desired targets may be viewed at the galactic poles. This gives essentially complete coverage for the lower galactic latitudes.

1.1.3 Scientific Instrumentation

The five SI bays can host a variety of specific instruments, and the long-term plan is to change SIs during orbital and ground refurbishments according to performance, scientific merit, capabilities of new instruments and the available budget. The SIs being prepared for flight at the initial launch of the Space Telescope are: the Wide Field and Planetary Camera (WF/PC); the Faint Object Camera (FOC); the Faint Object Spectrograph (FOS); the High Resolution Spectrograph (HRS); and the High Speed Photometer (HSP).

The WF/PC can perform imaging and filter photometry at two focal ratios (f/12.9 and f/30) with fields of view of 2.67 x 2.67 and 1.1 x 1.1 arc minutes. At both focal ratios, the full FOV is a four-part mosaic, with each quadrant sampled using an 800 x 800 charge coupled device (CCD) detector. By use of an organic phosphor coating the CCDs, the cameras should be sensitive from about 1150Å up to about 1.2 microns.

The FOC will be a photon counting system of 500 x 500 elements, working at F96 and F48, giving fields of view of 11.0 x 11.0 and 22.0 x 22.0 arc seconds from 1200 Å to 6500 Å. A slit spectrograph mode for extended sources and a coronagraph for working near bright stars will also be incorporated.

The FOS will provide low resolution spectra ($R \simeq 1200$) from about 1200 Å to about 7000 Å using an electron-bombarded linear silicon diode array as the detector (Digicon). An even lower resolution ($R \simeq 100$) mode will also be provided. The FOS will be capable of time-resolved (~10 msec) spectrophotometry and of ultraviolet spectropolarimetry.

The HRS will provide moderate ($R \simeq 24{,}000$) and high ($R \simeq 120{,}000$) resolution over the range from 1050 Å to about 3200 Å, again using Digicon detectors. A low resolution mode ($R \simeq 1000$) is also available from 1100 Å to 1700 Å.

The HSP will use four image dissectors and a photomultiplier tube to provide high accuracy photometry, ultraviolet polarimetry, and high time resolution (10 μsec) data. The wavelength coverage of the HSP is from 1150 Å to 8000 Å. This spectral range is analyzed through the use of ~48 filters.

Although not designed as a scientific instrument, the Fine Guidance System (FGS) will also be used to contribute to Astrometry by determining the relative positions of stars with accuracy of 0.002 arc seconds.

1.1.4 Launch and Refurbishment

During launch, the ST will be deployed from the Shuttle by crew members and checked out from the ground. As necessary, at about 2 1/2-year intervals, the Shuttle will revisit the ST and, after docking, will change system components and SIs. At approximately five-year intervals after each launch, the ST will be retrieved from orbit, refurbished on the ground and relaunched. Each ground refurbishment is planned to take approximately one year in duration.

1.2 SCIENTIFIC POTENTIAL OF THE SPACE TELESCOPE

1.2.1 Wavelength Coverage

The opacity in the ultraviolet of the Earth's atmosphere prevents the complete study of many astronomical objects, from interstellar clouds to the quasars. Many objects emit most of their radiation in the ultraviolet and/or have their most important spectral signatures in this wavelength range. There may even be objects that only emit in these regions and are not yet known.

Even for the visible region there are advantages to observations from space since the sky is darker, limited only by the diffuse radiation in the zodiacal light. The darkest optical regions should be about 1/4 the brightness. In the near infrared strong OH emission interferes with observations and the gains of ST will be even larger. As one goes further into the infrared, the advantages of the ST are two-fold. There is a continuous observing window available, and the ST will be diffraction limited.

1.2.2 Image Quality

The improved image quality available and high pointing stability permit very long exposures which promise to reveal structure in many astronomical sources. Regions of star formation, planetary nebulae and galactic nuclei are expected to show structure; unexpected features probably will be revealed.

Our knowledge of many solar system objects should improve because of study with the ST's high spatial resolution. Although Venus and Jupiter will have been studied in more detail by orbiters and flyby spacecraft, the ST will be able to measure them regularly at high spatial and/or spectral resolution. The outer planets, not subject to even temporary visits, will be revealed in new detail, as well as comets and asteroids.

The new angular resolution will also permit the direct application of the measurement of metric sizes of HII regions to significantly greater cosmological distances. This capability, together with the ability to study the form and composition of distant clusters of galaxies, should produce dramatic increase in the ability to apply today's methods of distance determination and will probably produce new, even more powerful methods.

1.2.3 Penetration to Faint Levels

The combination of high resolution, low background, increased sensitivity and relatively large aperture should lead the ST to reach 50 times fainter levels than those which currently can be reached using ground-based telescopes. For comparable detectors of insignificant internal noise, one expects the ST to reach levels about 2.7 magnitudes fainter per unit time than those which can be reached by a 4-m ground based telescope of 1 arc second seeing. The ST gains will be even greater because high quality conditions will continue for days instead of a few hours, and broader bandpasses may be used. This step should place white dwarfs in many galactic clusters within reach, allow the direct study of Cepheid variables in the Virgo Cluster, and permit detection of lower main sequence members of the Magellanic Clouds.

1.3 RELATIONSHIPS TO OTHER PROCUREMENTS IN THE SPACE TELESCOPE PROGRAM

1.3.1 System Hardware

The Optical Telescope Assembly (OTA) contractor is responsible for delivering the telescope that will provide the image quality necessary for ST science and the FGS which are used for all object acquisitions and performing many of the Astrometry functions.

The Support Systems Module (SSM) contractor is responsible for delivery of the integrated observatory including control, communications and acquisition systems.

1.3.2 Principal Investigators

The Principal Investigators (PIs) lead contracted scientific investigations that include the development and delivery of flight SIs and the basic data reduction software for each SI. The ST ScI must work closely with each PI to become familiar with the design, performance and operation of the SIs. The contractor must ensure that a smooth transfer for the operation and data reduction associated with each instrument and Astrometry is made from each PI to the ST ScI.

1.3.3 Science Operations Ground System

A separate contract will be let at about the same time as the ST ScI contract to develop the hardware and software for the entire Science Operations Ground System (SOGS). NASA has determined that it would be impractical for the ST ScI to develop these systems on a timely basis, compatible with launch of the ST. Not only should this method of providing support to the ST ScI be timely, but it would also avoid the temporary buildup of an unbalanced skill mix within the ST ScI.

Both the ST ScI and SOGS development will be managed from the GSFC. The GSFC will work closely with both contractors to guarantee smooth integration of both development efforts.

2.0 SCIENCE MANAGEMENT

The ST is the present culmination of telescope evolution begun by Galileo. Its unique capabilities are coupled with relative isolation of the astronomer from direct control, and a relatively long response time between one observation and its follow-on. These difficulties, with correspondingly greater rewards of observations at the limit of what is possible, require careful thought on the choices among, and the priority to be given to, various types of observing programs. The ST ScI should develop mechanisms for obtaining the best mix between long and short range problems, between individual and team research. It should evaluate the emphasis to be placed on high-risk observations at the limit of the instrument. In consequence, the ST ScI shall develop general policies, subject to review, using staff and advisory committees, to ensure the greatest possible scientific output of the ST. Such policies must evolve with the accumulation of experience. Similarly, science management shall consider the proper balance between the service and research activities of the scientific staff of the ST ScI.

The contractor shall develop and implement a science management plan which addresses NASA's overall scientific goals for the Space Telescope Project and the needs of the scientific community. In particular, this plan shall detail the methods to be used for carrying out the following specific tasks: implementation of NASA program guidelines and objectives; development and implementation of a policy for planning and scheduling observing time; promotion and support of research by the ST ScI scientific staff, development team members, and general observers; solicitation and selection of ST observers and archival users; evaluation of the scientific performance of the ST system and the performance of the ST ScI; provisions for the communication of scientific results from ST research programs to the scientific community and to the public; and provisions for a visiting fellow program.

2.1 PROGRAM GUIDELINES AND OBJECTIVES

2.1.1 Implement Long Term NASA Policy for ST and Recommend Appropriate Changes in Policy

The NASA Associate Administrator for Space Science shall retain overall responsibility for the ST Program and, in this capacity, shall provide general policy guidelines. Such guidelines will be provided in writing through the Contracting Officer and will be relevant to areas such as the NASA and European Space Agency (ESA) relationship; affiliations with other NASA programs; support of dealings with Congress; and SI refurbishment. The contractor shall provide a methodology for interpretation and implementation of such guidelines and for recommending policy changes.

Annual reviews shall take place jointly with the ST Project and the Associate Administrator for Space Science. The contractor shall prepare for such reviews to the extent necessary to discuss: (a) a summary of the past year's accomplishments (administrative and financial as well as scientific and operations); (b) the proposed activities and budget; (c) significant questions relevant to general policy including proposed changes to policy; and (d) long-range plans for ST, SI, and ST ScI development.

2.1.2 Establish and Implement Goals and Objectives of Current Science Programs

The ST ScI shall establish ST science program goals and objectives which are consistent with NASA's policies and plans, and are based on an assessment of the scientific potential and relevant past achievements of the ST. Broad observing goals shall be established which provide guidelines for:

(a) the interrelationship between ST research and the research of other space observatories and ground-based observatories; and (b) the relative apportionment of observing time to high- and low-risk scientific programs. Such goals shall take into account the commitments of ST PIs and other members of the development phase science teams as well as the commitments in the NASA/ESA Memorandum of Understanding (MOU). Such goals shall also take into account relevant developments in areas of instrumentation, programming and data management. The program shall also encourage an appropriate degree of innovative research, which might lead to completely new areas of research interest.

2.1.3 Recommend Necessary SI and ST Refurbishment or Modification

Refurbishment of the ST in whole (i.e., return of the ST orbiting observatory to the ground) or in part (i.e., replacing SIs or other equipment packages in orbit) will be under the purview of NASA's Space Telescope Program and Project Offices. The ST ScI shall recommend changes in the ST configuration and modifications to existing SIs in order to carry out the goals and objectives of the ST ScI's scientific programs. The ST ScI shall be expected to support the Program and Project offices in the evaluation of the merits of such changes. The ST ScI staff shall keep abreast of developments in areas which are pertinent to the problems of refurbishment.

2.1.4 Recommend New Categories for Scientific Instruments

The contractor shall recommend to NASA new categories of instruments which would carry out the scientific goals of the ST program which would enhance the scientific potential of the ST. The ST ScI shall exchange relevant information with the scientific and technical community to determine trends and fundamental new directions for SI development.

2.1.5 Promote International Participation

The contractor shall develop a methodology which will encourage full international participation in the science activities of the ST ScI. The contractor shall broadly disseminate plans for observer selection and sufficient information regarding the capabilities of the ST system so that the entire international Astronomy community is familiar with the opportunities which exist for research with the ST and with the data base maintained at the ST Science Institute Facility (ScIF).

The scope of this participation shall be worldwide. NASA's specific establishment of an MOU with ESA is not to be construed as a limiting factor but, rather, as a demonstration of NASA's intent to promote international participation in this program.

2.1.6 Science Data Rights Policy

The contractor shall establish and implement a policy which regulates access to all science data stored in the ST ScIF's archives. This policy shall be submitted to NASA via the Contracting Officer for approval and shall apply to ST ScI staff members, users of the ST and ST ScI systems, other members of the scientific community, and the general public. The policy shall treat such factors as: (a) privileged data files; (b) procedures and approvals required for routine access to data; (c) support services offered to data archive users; (d) reimbursement policy for services and data products; (e) terms of storage; and (f) data status changes.

The contractor shall ensure that observers have privileged access to their data and observing program details for a period of one year beginning after the science data and any associated spacecraft data are processed at the ST ScIF to a form suitable for analysis. In cases where the observing program is long term, the privileged access period shall be extended to a length to be determined by the ST ScI Director. During the period of privilege, only the observer shall have access to this material with the following exception: selected ST ScI staff members shall have access authorized as required to discharge operational responsibilities.

SI calibration data which is collected as part of a specific observing program at the request of the observer shall be considered part of the science data associated with that program. Limited access to this data shall therefore be mandated in accordance with the limits identified in the preceding paragraph, unless an exemption is granted by the observer. However, SI calibration data (using either internal or external sources) which are collected at the direction of the ST ScI to ensure proper working conditions of the SIs shall be considered public information. Access to this latter category of data shall be treated in the data rights policy in similar fashion to that accorded other archived data which is not subject to privileged access.

There is an opportunity for collecting data independent of proposed programs. The contractor's data rights policy shall ensure the best scientific use of such data.

2.2 OBSERVATION PLANNING AND SCHEDULING MANAGEMENT

2.2.1 Develop Long-Range Plans

The contractor shall establish and implement a long-range plan for the ST ScI which will provide direction for its short-term activities. At a minimum, this plan shall take the following into consideration: proposed modifications to the ST and its SIs; approved major changes to the ST ScI; programs conducted by other observatories; other NASA space programs; and approved ST long-term observing programs (e.g., studies of proper motion.)

2.2.2 Develop Ground Rules for Allocation of Observing Time

The contractor shall develop a methodology for allocation of observing time on the ST. Such a method shall preserve the commitments that NASA has already made to the PIs and other members of the development phase science team during the ST Announcement of Opportunity (AO) Process and those described in the NASA/ESA MOU (see Figure 2.1). Observations by the development phase science team outside the already NASA-approved investigative programs must be proposed under the General Observer (GO) selection process.

The ST is an observation facility for which a significant fraction of the observing time must be given to qualified scientists who are not connected with the ST ScI or the development phase science teams. Although it is desired that the ST ScI scientific staff members actively participate in the use of the ST, they shall be required to compete for observing time with other astronomers on the basis of scientific merit. This observation time allocation methodology shall address such potential problems as the balance between short- and long-term programs and targets of opportunity, and how these problems will be resolved.

The contractor shall develop and implement a policy regarding the treatment of targets of opportunity. This policy shall take into account the capability of the Space Telescope Operations Control Center (STOCC) and NASA communications network to respond. This policy shall incorporate the following considerations, as a minimum: (a) factors in deciding whether a specific target of opportunity merits attention; (b) standard procedures for deciding and implementing an interruption of current observations; (c) rescheduling of interrupted observations; (d) liaison between the personnel at the ST ScIF, SSC, and POCC to effect sudden changes in scheduled observations; (e) acceptance, storage, and time limitations placed on observation proposals dealing with targets of opportunity; and (f) the proportion of total observing time allocated to such special programs.

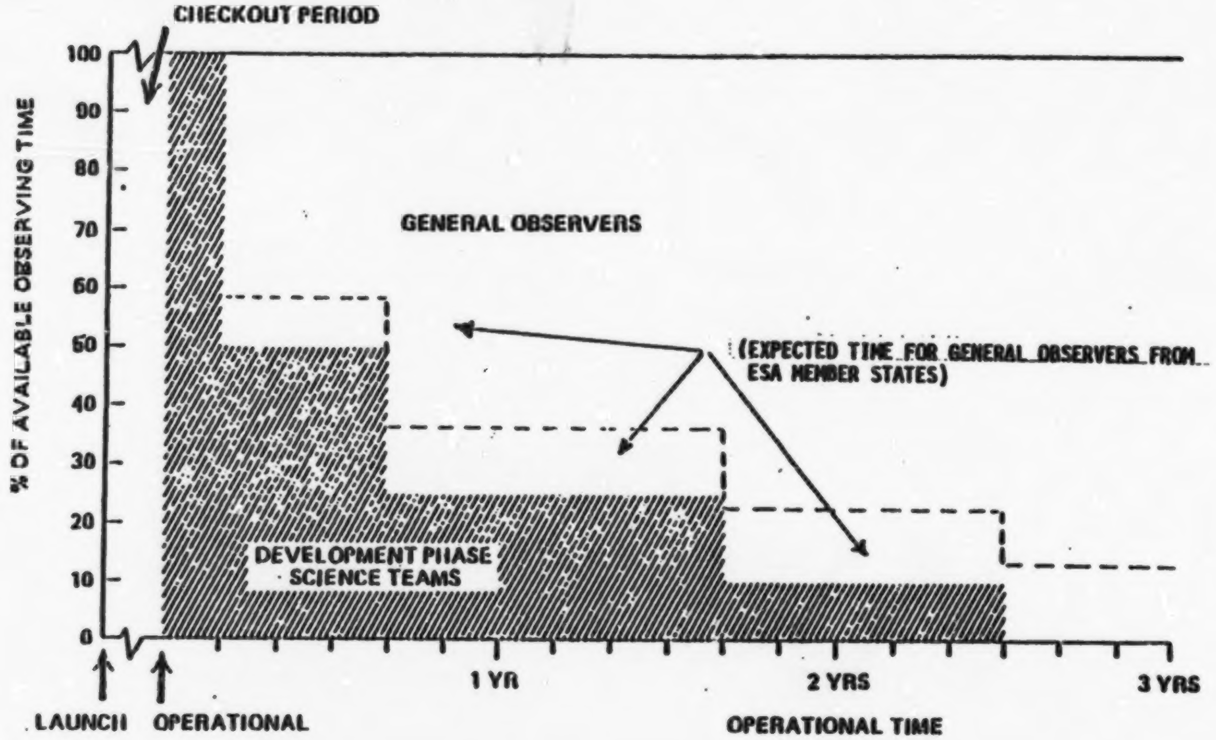

FIGURE 2.1. SPACE TELESCOPE OBSERVING TIME DISTRIBUTION

The expected ESA time is 15 percent on the average, including the initial phases of operation. It is made up of the expected time for general observers from ESA Member States plus the ESA time for the FOC. The ESA time for the FOC is equal to 1/7th of the total time allocated to the Development Phase Science Teams.

2.3 GENERAL OBSERVER SELECTION

2.3.1 Advertise ST Capabilities and Observing Opportunities: Collect Proposals

The contractor shall develop and implement a plan to inform the potential user community of the scientific observing potential of the ST and of the opportunity to submit proposals for its use. Solicitations for observing programs for the ST should not restrict in any way the types of programs to be proposed. Observer selection dates, criteria, and other associated general information shall be announced on a basis sufficient to provide opportunities for qualified observers of all foreign nations to submit proposals.

2.3.2 Selection of Observing and Research Proposals

The contractor shall establish and implement a method for the final selection of observing and research proposals. This method shall include the establishment of a group with broad representation from the astronomical community which will review all proposals for the use of the ST. This group shall include at least two representatives in accordance with the requirements of the NASA/ESA MOU. The nomination of the European representatives should be discussed jointly by ESA and the ST ScI. In this way, requirements for rotation of representation and geographic distribution can also be taken into consideration. It is anticipated that travel and per diem for the European participants will be covered by ESA. In addition, the selection methodology shall provide for NASA observers, at NASA's option, in the proposal selection activities.

Any approach finally adopted by the contractor shall ensure that selection shall be on the basis of scientific merit and shall place ultimate authority and responsibility for proposal selection and funding with the Director of the ST ScI. The results of the selection process shall be presented in writing within 30 days. The continuing, total observer program shall be consistent with commitments to ESA in the NASA/ESA MOU as well as commitments to the PI's and other Development Scientist members of the pre-launch science teams (see Figure 2.1). Observer and research proposal selection shall be carried out within the pertinent NASA policy guidelines, and shall coordinate current scientific goals, past accomplishments, current observing programs, and long-range objectives.

2.4 ST AND ST SCIENCE INSTITUTE PERFORMANCE EVALUATION

2.4.1 Self Evaluation of Overall Science Goals

The contractor shall conduct an internal review of the ST ScI's goals and achievements periodically and include the results of this self-assessment in the annual review with the NASA Associate Administrator for Space Science to complement the assessment by the ST ScI Visiting Committee (see Paragraph 2.4.2). An annual report shall be published describing accomplishments and listing other events occurring during the year. It shall also list the scientific papers published based on ST research.

2.4.2 ST ScI Visiting Committee

The contractor shall establish an independent committee of astronomers, other scientists, and appropriate qualified persons to assess periodically the ST ScI as a whole. This committee shall have access to all material necessary to perform their evaluation. The chairman of the Visiting Committee, selected by the contractor with NASA Program Office concurrence, shall report formally to the contractor. In addition, after giving notice to the ST ScI and the NASA Contracting Officer, the Chairman of the Visiting Committee shall report formally to the NASA Program Office. The committee shall meet no less frequently than annually. The ST ScI shall provide funds for the committee's activities including report preparation and distribution, members' travel on committee business, and other necessary expenses.

2.4.3 Evaluation of ST Scientific Performance

The contractor shall provide for an annual in-house review of ST total system scientific performance including an in-depth SI performance and astrometry operations review. The purpose of this review is to provide material for the annual review with the Associate Administrator for Space Science. This review shall evaluate the effectiveness of each SI vis-a-vis its design goals and the current scientific problems being addressed. It shall include inputs from PIs, Investigation Definition Team (IDT) members, the ST Users Committee, and/or others, as appropriate.

2.4.4 ST Users Committee

The contractor shall establish an ST Users Committee of observers, archive researchers and others as deemed appropriate to comment periodically on the ST ScI matters relating to routine observatory and archive research operations from the users' viewpoint.

2.5 SCIENCE COMMUNICATIONS

2.5.1 Symposia/Workshops

The contractor shall provide for the sponsorship of appropriate symposia, workshops, colloquia and seminars to serve as a forum for the dissemination of ST scientific results and to provide an atmosphere conducive to the pursuit of scientific research. Participation in such meetings shall be encouraged within the international scientific community. When appropriate, the proceedings of such meetings shall be prepared, published, and disseminated widely.

The contractor's staff shall also represent the ST ScI at professional meetings by giving talks on the capabilities and accomplishments of the ST and ST ScI.

2.5.2 Public Relations and Information

The contractor shall provide for the release to the press and the general public information which describes the scientific goals and results of the ST Project. NASA shall retain prior approval authority over all such releases. The goals shall be to maintain appropriately high visibility for scientific programs with the general public. The contractor shall also provide support to NASA for special information dissemination events and for preparation of educational materials.

2.6 VISITING FELLOW PROGRAM

The contractor shall establish the requirements and policy guidelines for a visiting fellow program at the ST ScIF. The program shall contain provisions for both senior and junior postdoctoral participation.

3.0 RESEARCH

The contractor shall develop and implement a plan to support research with the ST. This includes funding and expenses incurred in that research as well as providing guidance and assistance in its implementation. The staff is to be included in this plan as they are selected in the general competition. In addition, the contractor shall support its staff in preparing proposals and in other research which is related to the ST science program.

3.1 ST ScI USER FUNDING

The contractor shall fund U.S. scientists who have been selected as GOs or archival researchers to cover expenses incurred in their approved research program. These expenses include such items as related travel, computer time outside the ST ScIF, graduate student support, new software development for enhanced calibration or analysis of ST science data, and publications. Funding of scientists who are federal employees is subject to applicable government regulations. In addition, the ST ScI shall be responsible to contract for those ground based observations and theoretical studies without which the ST observations are impossible or incomplete.

3.2 ST ScI USER SCIENCE SUPPORT

The contractor shall develop and implement a plan to support ST observations by all users as well as user data calibration and analysis. This plan shall include provisions for the ST ScI staff to become thoroughly familiar with the SIs and ST science operations and capabilities so that the staff can: interface with ST observers to provide current observation-related information to ensure the most efficient use of the instruments; assist users in optimizing their proposed scientific programs; and promote and suggest correlative research programs with other space systems and ground observatories to obtain the best scientific return from the ST. The plan shall detail the method by which the ST ScI scientific staff serves as the point of contact for the individual observers from initial selection as users to final use of ST ScIF during data reduction and analysis.

The plan shall include methods for the staff's maintaining familiarity with calibration and analysis procedures and for staff interfaces with ST users to provide current best techniques to ensure efficient use of ST ScIF resources. It is intended that the ST ScI scientific staff develop and maintain a leadership role in this area. Within this plan, the contractor shall establish the limitations and working philosophy underlying collaboration between ST ScI staff and other ST observers. The goal shall be to obtain the best scientific results from the widest possible group of users. ST ScI staff participation in the scientific interpretation of a general observer's or archival researcher's data or comparison of the data with theory is expected only insofar as normal collaboration with the ST ScI staff occurs.

3.3 STAFF UNIQUE SUPPORT

The contractor shall provide and implement a plan for enabling and effecting research by members of the ST ScI scientific staff who, by direct competition, have been selected to use the ST or its archival data. The plan shall take into consideration NASA's estimation that it is reasonable to allow the scientific staff, on the average, approximately fifty percent of its time for ST related research. However, observing time and archival research programs shall be allocated to ST ScI staff on the same basis as for other GOs and other archival researchers.

This plan shall also provide for support to ST-related research by ST ScI staff members utilizing other space systems and ground observatories as needed to gain maximum benefit from their ST staff observation programs. The ST ScI may also conduct limited ST-germane theoretical research in support of the ST science program.

The contractor shall provide for the establishment and maintenance of liaison roles for the ST ScI staff with the general science community. This shall include liaison with national and international scientific bodies, university and educational institutions, the major national observatories and related space science programs. This specifically includes travel to professional meetings sponsored by these organizations.

4.0 SYSTEM OPERATIONS

The contractor shall be responsible for operation of the ST ScIF and the SCC. The contractor shall develop and implement plans and procedures which will fulfill the objectives detailed in this SOW. The system operations encompass such activities as Operations Management, System Engineering, Configuration Management, User Training, and Staff Training.

4.1 OPERATIONS MANAGEMENT

The contractor shall develop, maintain, and implement an operations management plan as part of the Technical Management Plan (MA-03) of the Data Requirements Document. The plan shall reflect proper consideration of the changing and maturing role of the ST ScI from the development phase through the launch and orbital verification phase, and into the operational phase. It shall also reflect the operation of the SSC, which will be staffed by the ST ScI. The plan shall describe methods and schedules for carrying out the specific technical functions identified in this SOW, particularly in Sections 5.0 and 6.0.

The contractor shall develop and implement a staff allocation plan that ensures 24-hour operation of the ST ScIF and SSC observation support operations as defined in Section 5.0. In addition, the contractor shall provide for optimized support of the post-observation data processing system operations as defined in Section 6.0. The contractor shall also establish shift plans and policies which assure appropriate communications between staff members and visitors and provide correlation of duties between staff and visitors operating at both the ST ScIF and SSC. Specifically, the contractor shall define the roles to be played by the GOs, and the ST ScI staff during the conduct of observations and data processing. The plan shall include the assignment of functions, definition of interfaces under nominal and contingency operations, and the allocation of necessary support resources. The contractor shall define and implement a host-guest relationship among the ST ScI staff and GOs and archival researchers that ensures responsiveness to the user's needs.

4.2 SCIENCE SYSTEMS ENGINEERING

4.2.1 Operational Procedures

The contractor shall develop, implement and maintain operational procedures for ST Science Operations at the ST ScIF and the SSC. These procedures shall cover all areas of science operations and shall include both personnel operations procedures and computer compatible procedures. These procedures shall cover the following broad categories: (a) Science Program Operations; (b) SOGS Operations and Maintenance; and (c) Mission Operations Interface. These procedures shall address all normal and contingency operations.

The science program operations procedures for ST ScI personnel shall include but not be limited to: (a) General Observer (GO) and Archival Researcher (AR) interface with operations personnel; (b) interruption of normal observations due to the appearance of a target of opportunity; (c) observation support system operations in the absence of an observer; (d) receipt and quality assessment of science data; (e) allocation of resources and assignment of priorities to users of the SOGS data processing capabilities; (f) recovery from major ground system failures, such as loss of the data transmission line between the ST ScIF and GSFC; (g) observer interaction with the Guide Star Selection System operations; and (h) staff, GO, AR, and non-ST community requests for access to the ST archives.

The SOGS operations shall include but not be limited to such functions as: (a) science observation plan and schedule generation; (b) guide star selection operations; (c) Observation Support System operations including monitoring data, processing data, evaluating data, and generating command requests; (d) Post Observation Data Processing System (PODPS) operations including data management operations, data archiving, data calibration, data analysis, and product generation operations; (e) library operations; (f) data delivery operations; and (g) data reporting procedures.

The ST Mission Operations interface shall include request for updated operational and command procedures for POCC resident and controlled items such as constraints for SI and Astrometry operations and SI optical focus and SI calibration. The contractor shall propose to the ST Mission Operations Office scientific requirements for modifications to SI C&DH operational constraints, contingency requirements, and software, when necessitated by science requirements or efficient observing operations.

4.2.2 Operational Modifications

The contractor shall support NASA in new ST SI development and modification activities which are contracted by NASA. In particular, the contractor shall provide assistance to new PI's on ST science operations as they affect SI designs, and shall participate in design reviews conducted by NASA regarding new SI developments. When new SI's are being phased in, the contractor shall propose software and operations changes. The contractor shall support SI and ST integration and verification activities during refurbishment and on-orbit replacement operations.

4.3 CONFIGURATION MANAGEMENT

The contractor shall develop and implement a Configuration Management Plan as described in the Configuration Management Requirements.

4.4 USER TRAINING

The contractor shall train users in the use of the operating systems at the ST ScIF and SSC as is appropriate. This includes interfacing with the observation support system and its operating procedures and the operating procedures and capabilities of the post observation data processing system. The contractor shall also have staff available to users to assist in the full use of both these systems.

The contractor shall provide and maintain users manuals for these systems and provide timely updates to the SI and ST Users Manuals.

4.5 STAFF TRAINING

The contractor shall provide a complete training program for the operations and maintenance of the Science Operations Ground System (SOGS), Guide Star Selection System (GSSS), the Science Data Analysis Software, and the science operations procedures that takes into account the training program provided by the SOGS contractor. The SOGS contractor will provide the initial training program that will be sufficient to ensure that ST ScI personnel are knowledgeable about the SOGS operations and maintenance and to ensure that the ST ScI can conduct the follow-on training of its staff, on these activities. The ST ScI shall assume full responsibility for the SOGS operations training program following ST launch readiness and the SOGS maintenance training program when it assumes responsibility for SOGS maintenance. The ST ScI shall provide the complete training program necessary to ensure the ST ScI staff's ability to operate and maintain the GSSS, science data analysis software, and the science operations procedures.

5.0 OBSERVATION IMPLEMENTATION

The contractor shall develop and implement an observational program which thoroughly considers: (a) preparation for observation; (b) conduct of nominal and contingency operations; and (c) potential problems of conducting dual operations at both the ST ScIF and the SSC.

5.1 PREPARATION FOR OBSERVATIONS

5.1.1 Guide Star Selection

The contractor shall provide initial guide star selection for targets designated by approved users after thorough discussion of optical approaches to acquisition. The ST ScI shall select candidate guide stars for each potential target identified by the user during the observation preparation period. The ST ScI shall select candidate guide stars for each target identified by the Mission Operations Manager in support of routine spacecraft operations.

5.1.2 Observation Planning

The contractor shall develop all science program planning, in accordance with prior commitments made with the ST development scientists and ESA for the ST program including GO observations, targets of opportunity, and SI calibrations. This responsibility shall begin with the first observational sequences planned for orbital operations of the ST. Planning requirements for orbital verification activity is an ST Project responsibility, but the ST ScI will be required to provide operations support.

The contractor shall analyze accepted observation proposals to extract planning inputs for: (a) instrument identification and inital operating mode; (b) science observation sequence, including target identification and changes; (c) science data quality/utility evaluation requirements; (d) command uplink requirements; and (e) other unique observation program operational requirements.

The contractor shall exercise the planning subsystem provided as part of the SOGS. The science requirements extracted from the user proposals shall be combined with files containing general ST, SI, Astrometry, communication network, and celestial capabilities and constraints to produce Observing Plans for submittal to the SSC. Content of these plans shall also be discussed with GOs to secure their understanding and acceptance. These plans shall be used to establish and control observing schedules. They shall also contain any plans for SI calibration.

As conflicts are uncovered during the ST scheduling process, which takes place at the STOCC, the ST ScI contractor shall update Observing Plans as required. The contractor shall also update the Observing Plans to account for unpredicted changes caused by science operations and observer problems.

5.1.3 Science Scheduling

The contractor shall generate Science Schedules using the Observing Plans produced at the ST ScIF. This activity shall be conducted using the scheduling system which is developed and installed at the SSC and provided as part of the SOGS. The science observations and SI operations contained in the plans shall be scheduled using files containing up-to-date data regarding the operational status and current and predicted ephemerides of the ST.

As part of the science scheduling process, the contractor shall select final guide stars for target acquisition. This selection shall be made from the candidate guide stars supplied in the Observing Plan. This final selection shall be performed following review of the ST attitude and ephemerides and the status of the SIs.

The contractor shall also provide changes to the Science Schedules which are required due to changes in the observing plans or conflicts uncovered by the POCC. Modifications of the Schedules in response to POCC requests shall be made: (a) to accommodate communications network incompatibilities; and (b) due to violations of ST constraints.

5.1.4 ST Science Institute and STOCC Scheduling Interfaces

The contractor shall coordinate the implementation of science Observing Plans and Science Schedules with the appropriate persons at the STOCC. The Payload Operations Control Center (POCC) will have ultimate responsiblity for ST mission scheduling which coordinates the science schedule, spacecraft operations requirements, and requirements for NASA support. The contractor shall develop a management structure which assures an efficient flow of activities from the observation planning through the observation scheduling processes and which takes into account the fact that the observation planning is performed at the ST ScIF and that science scheduling is performed at the SSC.

The contractor shall include in the ST ScIF and STOCC interface structure a method for dealing with potential schedule changes at appropriate points during the observation preparation period, within constraints identified by the ST Mission Operations Manager. The contractor shall provide for day-to-day problem resolution at the operation level.

5.2 OBSERVATION SUPPORT

5.2.1 General Observer Support

The contractor shall support observers in observation support operations at the ST ScIF or SSC by: (a) performing or assisting in the performance of target acquisition verification; (b) performing or assisting in the performance of data quality and utility analysis; (c) requesting or assisting in the requesting of real time commands to modify observation sequences or parameters; and (d) selecting or assisting in the selection of pre-planned observation scheduled options.

5.2.2 SI Operations Monitoring

The contractor shall assure the continuous monitoring of SI operations and calibration as part of ongoing SI maintenance operations. Further, the contractor shall develop operating procedures which provide SI status information to the user as required during the conduct of operations. Changes in status which affect the quality of the observation(s) being made shall be brought to the attention of the user in a timely fashion to avoid the unnecessary loss of observation time.

The contractor shall verify appropriate SI operation, and provide assistance in the event of an anomaly. The contractor shall prepare "workaround" procedures wherever feasible. The contractor will support joint planning activities with the ST Project Office and the PIs to ensure that fully adequate SI engineering capability is readily available through the ST Project.

The contractor shall compile and maintain operational records, reports, and schedules identifying such items as SIs utilized, targets observed, exposure times, and acquisition and operational problems. These documents shall be maintained for detailed analysis and long-range planning purposes. The documentary records shall also be utilized by the contractor at the SSC to evaluate the operational effectiveness of the SSC and POCC interface and shall be available upon request by the Contracting Officer.

6.0 POST OBSERVATION OPERATIONS

The contractor shall implement the post observation operations plan developed under Section 4.0 of this SOW. Post observation operations include all of the operations described in this section.

6.1 DATA HANDLING OPERATIONS

6.1.1 Data Management System

The contractor shall operate and maintain a data management system for science and related engineering data. The system shall be used to monitor and control the utilization of available data by the entire ST ScI staff and visitors.

6.1.2 Science and Engineering Data Receipt and Storage

The ST ScIF shall receive science and related engineering data. This shall include SI science and engineering data, Astrometry data, and project approved spacecraft and ground system data required for the analysis and interpretation of the science data. The contractor shall utilize the SOGS and develop procedures to inspect incoming data; separate it into appropriate categories; perform quality checking; evaluate trends in amounts, quality, and other characteristics of the data; validate time stamps and assure appropriate correlation of different data packages; issue periodic data summaries and quality control reports; and assign all data to appropriate temporary and permanent storage files.

The contractor shall create a system which provides safeguards for all science and engineering data received and stored in permanent data archives. In consideration of the expected life of the ST, the system of archiving shall be compatible with extending the storage beyond the basic contract period.

6.1.3 Data Accountability

Records shall be kept by the ST ScI showing the whereabouts and status of all data products to be produced for and shipped to observers. A monthly data management report shall be delivered to the Contracting Officer.

6.2 ROUTINE SCIENCE DATA PROCESSING

The contractor shall perform standard calibration routines, the purpose of which are to remove instrument signatures from all of the raw science data received. The contractor shall assure the timely performance of this function utilizing the SOGS. These calibrations, performed on data which have undergone the standard data handling operations described above, shall be completed within twelve hours (as a design goal) after receipt of the data.

6.3 SCIENCE DATA ANALYSIS PROCESSING

6.3.1 Interactive Data Processing

The contractor shall maintain and operate the SOGS interactive data processing system. This system will be used by users to evaluate the effects of applying various calibration and analysis programs to selected science data, for the purpose of extracting scientific information from the data.

The contractor shall be prepared to modify the baseline interactive data processing system as a function of changing user population over time. The higher percentage of new users involved with the ST Program each year, as well as the knowledge gained through experience with operating the system, should be regarded as factors which influence the optimization of this system.

6.3.2 Accommodation of User Software

The contractor shall provide for the accommodation of user-unique software in the interactive data processing system at the discretion of the ST ScI Director or designee. Software developed under GO or archival research funding may become part of this software system of the ST ScIF.

The contractor shall also provide adequate documentation to prospective users to enable them to prepare software which will be fully compatible with this system resident at the ST ScIF.

6.4 DATA PRODUCT GENERATION

In general, the contractor shall provide two types of data products at the ST ScIF: (a) computer compatible mass storage (e.g., tapes or discs) of raw, calibrated, and/or analyzed data; and (b) hardcopy products like plotter outputs, photographic materials, and others. The contractor shall establish, as part of the operations plan, a policy regarding the amount of data to be distributed via a computer compatible mass storage medium and/or hardcopy products and present this policy to the Contracting Officer for review and approval at a time to be determined mutually by the contractor and the Contracting Officer.

6.4.1 Computer Compatible Mass Storage Products

The contractor shall provide the resources necessary to operate the SOGS hardware and associated software to produce computer compatible mass storage products containing appropriate data as requested by users and approved by the Director. As a minimum, the observer shall receive, costed as part of the observing program, a magnetic record of all the calibrated data collected to support the observing program.

6.4.2 Hardcopy Data Products

The contractor shall provide the resources necessary to operate the SOGS hardware and associated software to produce hardcopy data products in response to approved requests by users of the ST ScIF.

For public requesters, the contractor shall determine the total costs of preparing each hardcopy product and establish prices which assure full recovery of such costs. NASA-provided funds shall not be used to underwrite the generation or distribution of products requested by the public. Distribution of data to the public shall not interfere with normal ST ScI science operations activities nor violate user-privileged rights to data. The plan for implementing such public requests for data shall be submitted to the NASA Contracting Officer for review and approval.

6.5 LIBRARY ESTABLISHMENT AND SUPPORT

The contractor shall establish and maintain a library of astronomical, engineering, and other data which is relevant to the ST Program, and is required by staff and visiting scientists using the ST ScIF. The contents of the library shall be determined by the contractor in full consideration of other potential sources of the data, and the need for timely acquisition of the data by the library users. The contractor is expected to utilize modern technology which has been established for library sciences, and which is compatible with the advanced nature of ST. As a part of the operations plan, a policy defining the use of the library shall be developed.

The library shall contain updated SI and ST design descriptions, users manuals and other materials potentially required by the ST ScI staff, approved GOs, and archival researchers. It shall contain historical files of users manuals and data processing and analysis software. Reference texts, charts, periodicals, and other material relating to the science of astronomy shall also be provided, but only to the extent necessary to supplement other facilities readily available to staff members and guest users. An indexed raprint file of journal papers, research notes, and other published material resulting from ST ScI funded research shall be maintained.

The library shall compile, maintain, and disseminate records, reports, and schedules of the ST science observations. Cross-indexing shall be provided, covering at least the following: SI, target, object designator, target class, astronomical objective, and GO. Technical and scientific indices of all observations shall be generated. The library shall also develop summary results of the science programs and arrange for their timely dissemination to an appropriate audience.

7.0 MAINTENANCE

The contractor shall provide for the maintenance of all software and hardware at the ST ScIF and the SSC. This shall include maintaining documentation for SOGS hardware and software. In addition, it includes maintaining complete documentation (e.g., maintenance, operations, and user manuals) for ST ScI purchased or developed hardware and software.

7.1 OPERATIONS SOFTWARE MAINTENANCE

The contractor shall maintain the operations software and its related documentation in accordance with the ST Project approved, ST ScI developed, configuration control procedures. This shall include the following:

- o The contractor shall modify, integrate, and test changes to the SOGS software.

- o As approved in the GO and archival researcher selection and contracting process, the contractor shall implement unique data analysis software development.

- o The contractor shall assist in the development, integration, and test of appropriate data calibration, analysis, and observation support system software developed for future SI's and planned for integration into the ST ScIF.

- o The contractor shall maintain data base files used to support the ST ScIF and SSC software systems.

As approved in the GO and archival researcher selection and contracting process, the contractor shall provide additional support to users who supply software that will be included in the ST ScIF. This includes the following:

- o The contractor shall provide assistance in the user's effort to understand and utilize the ST ScIF.

- o The contractor shall provide assistance in the testing and execution of user-supplied programs at the ST ScIF (as approved in the GO selection process).

7.2 ADMINISTRATIVE SOFTWARE DEVELOPMENT AND MAINTENANCE

The contractor shall provide and maintain the ST ScI administrative software and its related documentation, including: accounting and billing, resource management, logistics, and other support functions which are determined to be needed for ST ScI operations.

BEST DOCUMENT AVAILABLE

7.3 HARDWARE REPAIR, CALIBRATION, AND WEAROUT

The contractor shall provide for the repair and calibration of all ST ScIF and SSC equipment. This is to include replacing equipment when the existing equipment cannot be kept operational at a reasonable cost.

7.4 HARDWARE CHANGE AND AUGMENTATION

The contractor shall provide, as required, for the procurement, installation, and checkout of (a) additional equipment, and (b) improvements (e.g., new models) to existing equipment. The contractor shall not initiate any hardware changes and/or augmentations until approval from the Contracting Officer is obtained.

8.0 BUSINESS MANAGEMENT AND ADMINISTRATION

The contractor shall develop and implement a business management and administrative program to accomplish all functions necessary to operate the ST ScI. The program shall include, but not be limited to: personnel management, documentation, and financial and contracts management.

8.1 PERSONNEL MANAGEMENT

The contractor shall develop and implement a personnel management plan for ST ScIF and SSC positions. This plan will cover all personnel management functions required to meet this SOW, including the NASA/ESA ST MOU staffing requirements. It shall include, but not be limited to, a staffing plan and the identification of key positions.

8.2 DOCUMENTATION

The contractor shall document plans and activities of the ST ScI throughout the developmental and operational phases of the ST Project. The contractor shall also provide for the timely generation and distribution of all required documentation described in the Data Requirements Document.

8.3 FINANCIAL AND CONTRACTS MANAGEMENT

The contractor shall develop and implement a budgeting and accounting plan for allocation and management of financial resources. This plan shall take into account long-range fiscal planning and internal expenditure records (e.g., payroll, office supplies, and travel), including resources emanating from outside NASA. ST ScI acceptance of funds from sources other than NASA shall require prior approval from the Contracting Officer. In addition, the contractor shall identify and account for any unique budgeting and accounting requirements for the operation of the ST ScIF.

The contractor shall develop and implement a contract management plan which ensures contracting support for hardware, software, facilities, research programs, and purchasing activities.

9.0 FACILITIES

The contractor shall develop and implement a facilities management plan that takes into account the site and building acquisition and maintenance, utilities, furnishings, shipping and receiving.

The contractor shall provide a site and facilities with its work spaces appropriately configured for performing all designated ST ScI functions. Locations for the ST ScI site and building are limited to geographical United States. No NASA site or facilities will be available as a location for the ST ScI site or building.

The contractor-provided facilities for the on-line science operations consoles, the data calibration and analysis system, the product generation system, data archive, and the guide star selection system shall have environmental control suitable for ADP systems, storage of master data tapes, and storage of standard reference plates.

The contractor shall provide work space for staff and users which are conveniently located to the operations consoles and the ADP user interfaces. Observers shall have ready access to the consoles and users to the ADP dispatch and user terminals.

The data archive facility shall have protection against data loss, including redundant storage as required. In addition, it shall have access control and security. The product generation facility shall include a photographic dark room and temporary storage for all products generated.

The contractor shall provide office space and specialized work spaces to accommodate all administrative, scientific, engineering, and support staff engaged in operation of the ST ScIF. The contractor shall provide space for equipment, supply logistics, conference rooms, and such other specialized facilities as may be required for the operation of the ST ScIF.

The contractor shall provide office space and specialized work space for temporary use by ST ScIF users, committees, visiting fellows, and SOGS contractor employees while they are in residence at the ST ScIF.

At a minimum, the ST ScI building shall meet the requirements of the Space Telescope Science Institute Facility (ST ScIF) to Science Operations Ground System (SOGS) Equipment Interface Control Document (IRD), STR-16. In addition, the building design shall accommodate a reasonable expansion of equipment and staff during the operational era.

10.0 PRE-LAUNCH PREPARATION AND IN-ORBIT VERIFICATION

As part of preparation for the operations phase of the ST Program, the contractor shall develop specific hardware and software, participate in development phase working groups, interface with existing contractors, hold and support major reviews, and support integration, test, and verification activities as defined in this section of the SOW.

10.1 SOGS CONTRACTOR INTERFACE

The ST ScI shall appoint a representative who shall provide liaison with respect to the technical direction and monitoring of activities relating to the SOGS development. This representative shall be collocated at the GSFC during the development phase. The contractor shall actively participate in all design reviews of the SOGS system and subsystems.

10.2 PI AND ASTROMETRY SCIENCE TEAM INTERFACE

The contractor shall establish working interfaces with the IDTs and the Astrometry Science Team (AST) to ensure that, following in-orbit verification, the ST ScI has the means of executing its full responsibility for SI and Astrometry science operations and data management.

The PIs will provide: (1) support for pre-launch verification of ST mission and science operations procedures and software, and (2) the personnel who will participate in pre-launch operations simulations and training and will be responsible for the operations and orbital performance verification of the engineering and scientific performance of the instrument.

The PIs will provide support for launch and postlaunch verification operations (in-orbit instrument checkout). PI team support personnel will be required to support postlaunch operations at the SSC and ST ScIF for approximately 2 months following launch.

Through the ST Announcement of Opportunity for Space Telescope, AO No. OSS-1-77, the PIs are committed to "have an on-going responsibility during the period after post-launch checkout to assist in the operation, calibration, data processing associated with their instruments, and to assist other observers in the use of their instruments." The ST ScI contractor must assume the responsibility for whatever arrangements it determines to be necessary to ensure continued operation during and after the transition phase.

10.3 ST WORKING GROUP INTERFACES

During the development phase, the contractor shall appoint a voting member to the ST Mission Operations Working Group (MOWG) and the ST Data and Operations Team (DOT). The contractor shall participate as an observer to the Assembly and Verification Working Group (AVWG). The Director of the ST ScI shall serve as a voting member of the Space Telescope Science Working Group (ST SWG). In this capacity, the Director will not only represent the ST ScI but will also serve as the point of contact between members of the ST SWG and ST ScI personnel.

For each working group, the member shall represent the ST ScI at regularly scheduled meetings, and support other activities as defined by the Working Group Chairperson. The representatives shall provide inputs relating to those functions for which the ST ScI has responsibility in the operational phase.

10.4 CONFIGURATION CONTROL BOARD INTERFACE

The contractor shall appoint a representative to the ST Level III GSFC Configuration Control Board (CCB). The ST ScI representative will be responsible for reviewing Configuration Change Requests (CCRs) submitted by the ST ScI and other contractors which have an impact on ST ScI or SSC operations.

10.5 HARDWARE ACQUISITION

10.5.1 SOGS Hardware

The contractor shall be provided the SOGS hardware. The contractor shall provide support to the SOGS contractor who is responsible for its installation, checkout, and test. The contractor's representative at GSFC shall coordinate with the ST ScI Technical Officer regarding the integration of this hardware. The contractor shall provide for the review of development, operational and maintenance documentation associated with SOGS hardware. The ST ScI shall provide the necessary facilities support to the SOGS contractor during integration and test of the SOGS in the ST ScIF.

10.5.2 Guide Star Selection System (GSSS)

The contractor shall provide, install, and test the hardware and software associated with the GSSS as specified in the Space Telescope Science Institute Guide Star Selection System (GSSS) Specification. The contractor shall also consult as necessary with the Astrometry Science Team regarding the development, installation, checkout, operations, and maintenance of the GSSS. The contractor shall provide inputs and analyze and review the SOGS contractor developed GSSS to SOGS interface control document.

10.6 SOFTWARE ACQUISITION

10.6.1 SOGS Software

The contractor shall be provided the SOGS software. The contractor shall provide support for all software integration and test at the SSC and ST ScIF. The contractor shall provide for the review of development, operational, and maintenance documentation associated with SOGS software. The ST ScI shall provide the necessary facilities support to the SOGS contractor during integration and test of the SOGS at the ST ScIF.

10.6.2 Science Data Analysis Software

The contractor shall prepare and implement a plan for the development and documentation of a baseline set of data analysis software to be part of the PODPS. This software shall be developed by the ST ScI contractor and shall meet the interface requirements of the PODPS. The ST ScI contractor shall review, analyze, and provide inputs to the interface control documentation developed by the SOGS contractor. The ST ScI shall support the SOGS contractor who will integrate the science data analysis software into the PODPS.

At a minimum, the science data analysis software shall satisfy the requirements of the Space Telescope Science Institute Science Data Analysis Software Functional Specification. The contractor shall work directly with the PIs, the AST Leader, and the ESA Science Team representative in preparing the software for analysis of the calibrated data from each of the SIs and analysis of the edited data from the FGSs. Analysis software developed by each science team will be evaluated for incorporation into the ST ScI developed science data analysis software baseline.

10.7 REVIEWS AND SUPPORT ACTIVITIES

10.7.1 ST ScI Contractor Reviews

A. Program Management Review (PMR)

The science, operations, and business management reviews shall be held at GSFC to evaluate the approach to and status of each WBS element. The PMRs must assure NASA that the staffing, facilities, GSSS development, science program, etc., are progressing on schedule and within cost. The reviews require the concentrated effort of a broad cross-section of ST ScI personnel and may result in major redirection of program effort if necessary. The reviews must be complete evaluations of the status and planned activity of each WBS element.

B. GSSS Preliminary Design Review

The contractor shall document and present all preliminary design efforts, including the rationale for the system design involved. The contractor shall provide a detailed correlation of the GSSS functional requirements with the contractor-developed system design specification.

The contractor shall provide a preliminary allocation of functional requirements to hardware and software requirements. A preliminary estimate of the number of lines of code and a software hierarchy shall be provided. The contractor shall provide detailed requirements for any related ground observing program.

C. GSSS Critical Design Review

The contractor shall document and present all final system design efforts. This system design review shall cover all external interfaces, internal interfaces, computer systems, and major GSSS subsystems. The contractor shall ensure that at the Critical Design Review the following conditions prevail:

- all computer operating and management systems designs, including designs of any executive software required are complete;
- performance and operations objectives of the functional specification can be met;
- all hardware purchase specifications and vendor identifications are complete;
- all test documentation shall be identified and the overall GSSS test and verification plan shall be complete;
- preliminary test plans shall be available and shall include, as a minimum, hardware acceptance tests and software functional tests;
- the detailed requirements for all applications software shall be complete;
- the estimate of the number of lines of code shall be updated;
- all purchase specifications and vendor identifications for commercially available software shall be complete;
- verification that the design meets external interfaces shall be complete;
- a utilization study for the computer system shall be complete.

D. Science Data Analysis Software Preliminary Requirements Review

The contractor shall document and present a detailed analysis of the Science Data Analysis Software Functional Specification. The contractor shall provide a detailed definition of each analysis program to be developed for each functional requirement. Compliance with external interfaces shall be demonstrated. Analysis software sizing estimates and computer system usage requirements shall be identified. Data sources and products shall be specified. Preliminary test requirements shall be defined.

E. Science Data Analysis Software Critical Design Review

The contractor shall document and present the detailed science data analysis software design. The contractor shall demonstrate that the detailed designs for all analysis software programs are complete, that interfaces are met and that detailed test plans are complete. Updated software sizing estimates and computer usage requirements shall be provided.

F. Facility Readiness Review at ST ScIF

A review will be held to assure that the ST ScI facility will be available to support the requirements of this SOW.

G. Progress Review

A review of ST ScI progress shall be held on a quarterly basis. It shall address current status, major planned activities, problem areas and proposed solutions, and schedule status.

H. Monthly Status Meetings

A monthly status meeting shall be held in those months when there are no other formal reviews scheduled. It shall address current technical, schedule, and resource status and problems areas.

10.7.2 Other Reviews

The contractor shall attend and participate in all major ST reviews. The contractor shall participate in the review meetings, and provide analysis of all review documentation and presentations from the viewpoint of science operations.

10.7.3 Verification Activities

The contractor shall participate in the Verification and Acceptance Program (VAP) for the SIs and SI C&DH and in the ST Assembly and Verification Program as an observer. Although no direct activities in developing procedures or conducting simulations and tests are required, the contractor shall provide personnel to observe all aspects of the program.

10.8 MISSION OPERATIONS GROUND SYSTEM (MOGS) INTEGRATION AND TEST

The MOGS integration and test encompasses all activities associated with combining the ST ground system major elements into the MOGS and verifying MOGS operation. The major elements are the Space Telescope Observatory Management System (STOMS), SOGS, GSSS, and science data analysis software. The MOGS integration and test will be performed in two phases. Phase I is the integration of the interfacing hardware and software and the testing and verifying that the interface complies with the related ICD. Phase II is the operational verification of the MOGS.

10.8.1 Phase I

Phase I will be performed using relatively small components of each of the major elements, the objective being to verify compatibility across the specific interface being tested. The test requirements, plans, and procedures for each Phase I test shall be prepared by the same organization that has developed and maintained the related ICD (e.g., the SOGS contractor will prepare the overall test requirements, plans, and procedures for the SOGS to GSSS interface). The other interfacing entity shall review these documents for completeness and accuracy and shall provide inputs related to its unique responsibilities (e.g., the ST ScI contractor shall review the SOGS to GSSS test requirements, plans, and procedures and will provide the GSSS unique test requirements, plans, and procedures). The GSFC will approve and control these documents. Each interfacing organization shall support the test with the necessary test and operations personnel and materials and shall prepare a test report.

10.8.2 Phase II

Phase II will be performed using large components of each of the major elements; the objective being to verify the operation of the MOGS. The Mission Operations contractor (i.e., for the POCC) and the ST ScI shall provide the operations personnel to perform these tests. The Mission Operations contractor shall act as lead contractor in preparing documentation for these tests. The ST ScI shall provide test requirements, plans, and procedures inputs, and shall provide test reports for this activity. These documents will be approved and controlled by the GSFC. This phase will include testing across multiple interfaces. It will involve the use of simulated and real ST data and will test the MOGS data handling capacity and the ability of the MOGS to respond to system failures. During this phase the SOGS contractor will provide technical consultant support to the ST ScI and Mission Operations contractor. SOGS hardware and software maintenance during this activity will be performed by the SOGS contractor. The ST ScI contractor shall coordinate training of SSC and ST ScIF personnel with the SOGS contractor to ensure that such training is phased to adequately support the ST ScI's role in MOGS Integration and Test Phase II.

10.9 OTHER SUPPORT

10.9.1 ST to STOCC Compatibility Test

The ST to STOCC Compatibility Test demonstrates that the MOGS is capable of controlling the ST and receiving both science and engineering data. It involves a direct interface with the ST located at the ST integration and test site at LMSC. The LMSC is responsible for the development of the test requirements, plans, procedures, and reports. The ST ScI personnel shall prepare SOGS-related requirements and procedures and will operate that portion of the SOGS supporting this test. The SOGS contractor will provide technical support to the ST ScI and the Mission Operations contractor. SOGS hardware and software maintenance during this activity will be provided by the SOGS contractor. The ST to STOCC compatibility test is controlled by the availability of the ST and will, therefore, be conducted following appropriate Phase I MOGS testing and prior to the completion of the Phase II MOGS testing.

10.9.2 Mission Simulation

Mission Simulation is performed to certify that all operations personnel are capable of proficiently implementing required operations procedures. This activity is based on the assumption that those portions of the MOGS used in this simulation have already passed MOGS integration and test. Mission simulations must exercise all launch-critical procedures on all operations shifts. Mission simulation encompasses contingency procedures, procedures for post-launch activities, and proficiency rehearsals for all operating shifts. The ST ScI contractor shall coordinate training of ST ScI operators of the SOGS to ensure appropriate readiness for Mission Simulation. SOGS hardware and software maintenance during this activity will be provided by the SOGS contractor. The ST ScI shall provide all staffing necessary to operate the SOGS and GSSS in support of ST Mission Simulations.

10.9.3 Ground Readiness Review

A ground readiness review will be conducted by the GSFC Design Review Office to determine that the MOGS is operationally ready to support the ST mission. The ST ScI contractor shall prepare and present necessary review material to support this activity.

10.10 IN-ORBIT VERIFICATION AND INITIAL OPERATIONS SUPPORT

The contractor shall ensure that the ST ScIF and SSC are totally operational at launch. Operational, management, and support personnel shall be responsible for carrying out all of the functions identified in the SOW, beginning at launch. The contractor shall supply all of the material and services required to ensure an efficient and timely transition during this period from SOGS contractor maintenance to ST ScI control and responsibility.

The contractor shall assist the SI IDT members and their engineering support personnel in conducting their assessment of SI performance. The operation of the consoles at the ST ScIF and SSC shall be performed by ST ScI personnel in support of the development phase teams. Technical consultation support and SOGS hardware and software maintenance during this period and until launch plus 6 months will be provided by the SOGS contractor as required.

Required data processing of science and SI engineering data which falls within the normal range of ST ScI functions shall also be conducted in support of the development phase teams at their request. The ST ScI facilities shall be available for use by the IDTs and AST for initial calibration activities at a level that exceeds normal operation.

The contractor shall provide for the receipt, indexing, and archiving of all science and SI engineering data produced during the In-Orbit Verification Program. Such data shall be assumed to be proprietary and access shall be limited to persons identified by the Contracting Officer.

ADDITIONAL STATEMENTS FOR THE RECORD REGARDING THE SPACE TELESCOPE SCIENCE INSTITUTE

The following four statements were requested by Chairman Flippo in order to complete our record. The letters requesting the statements were identical and a sample letter is included to show the questions that were asked.

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MINORITY STAFF DIRECTOR

June 2, 1982

Dr. Thomas Donahue
Chairman
Space Science Board
c/o Dept. of Atmospheric and Ocean
 Sciences
University of Michigan
Ann Arbor, Michigan 48709

Dear Dr. Donahue:

Recently the Subcommittee on Space Science and Applications held hearings on the Space Telescope being developed by the National Aeronautics and Space Administration. The development of the Telescope now appears to be moving along quite well. One witness stated his belief that even though we have high expectations the Telescope will lead to even greater scientific advances than anticipated. As you know, the realization of such expectations will depend on the successful operation of the Space Telescope Science Institute. As the Telescope proves its value, demands on the Science Institute may make successful operation even more difficult.

The Subcommittee believes that the Space Telescope and the Science Institute will be successful, but given the large investment and the apparently high optical performance that will be achieved, we want to maximize their success. Looking ahead, we know that in several years we will be conducting oversight hearings on the Science Institute. I am writing today to ask you to help in this future oversight process by providing a statement for the record of our recent hearings. We would like a statement on criteria by which we could judge the effectiveness of the Science Institute. You might comment on how you think the Science Institute should be operated, and how we can judge whether or not it is being so operated.

As an example, let me mention one question that is sure to arise. The competition for observing time is sure to result in some bitterly disgruntled observers. We want to assure that sound, excellent, and vigorous science is done but we also want to assure that original concepts are not rejected out of hand (perhaps concepts not fitting current theoretical paradigms). Thus, the process for selecting observers and allotting time will be very important. To preclude charges of favoritism of one kind or another, it might be good that the selection process be very open. Our experience--having to go on the record and account for our views daily--leads us to believe that an open, accountable selection process is healthier than a closed process. Should the Telescope observer selection process be open, perhaps along the lines of the N.I.H. review process? How can we in Congress ensure that a closed process is fair (since by definition a closed process cannot be accountable)?

We are determined to do what we can to ensure the success of the Science Institute. Your comments on what we should do and what we should ask NASA to do concerning the Institute would be very helpful to us. Therefore, I am offering you this opportunity to provide a short statement for the record of our hearings. The statement should be no more than ten pages and it would be convenient if we could receive it by approximately June 18, 1982. Should you have any questions you could contact Dr. Radford Byerly of the Subcommittee staff (202/225-8102).

I am looking forward to your response.

Sincerely,

RONNIE G. FLIPPO
Chairman, Subcommittee on
Space Science and Applications

F/rm

cc: Bruce Gregory

BEST DOCUMENT AVAILABLE

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June 14, 1982

The Hononorable Ronnie G. Flippo, Chairman
Subcommittee on Space Sciences & Applications
U. S. House of Representatives
Rayburn House Office Building
Washington, D. C. 20515

Dear Rep. Flippo:

I am responding to your letter of 2 June addressed to Dr. Thomas Donahue. Dr. Donahue requested that I respond in view of my greater familiarity with STScI both in my current role as chairman of the Space Science Board's Committee on Space Astronomy and Astrophysics (CSAA) and my previous service on the National Academy of Sciences' "Hornig Committee" which provided the recommendations which led to STScI's formation.

In response to your question regarding allocation of observing time, I firmly believe that the procedures currently envisioned for the institute offer the possibilities for both fair and imaginative assignment of ST time. The model adopted by STScI is similar to that currently used by other national astronomical facilities (e. g. Kitt Peak National Observatory, National Radio Astronomy Observatory). In these observatories a Time Allocation Committee (TAC) reviews all applications for time and provides for the director an ordered list of programs deemed to be of high scientific merit. The TAC is composed of distinguished scientists drawn both from the community at large (in the majority) and from the observatory staff; members are identified publicly well in advance of time applications. The observatory director uses the list provided by the TAC, combined with his own judgment, to make the final allocation of time. While in most cases the recommendation of the TAC is followed in assigning 85-90 percent of the time, the observatory director can and does assign time to support 1) innovative programs, 2) needs for testing new modes of instrumental or telescope operation, 3) long-term and/or highly challenging programs and 4) "routine" work viewed as critical to the success of other scientific programs but which, by itself might not carry a high TAC rating.

Proposals not accepted for time are returned with varying levels of comments regarding technical and/or scientific deficiencies and in some cases specific recommendations for improving the proposal. This procedure for allocating time has won wide acceptance in the community over the past decade and is believed by most astronomers to be fair.

Moreover, the community, through periodic review by Visiting Committees to the observatories can review the overall effectiveness of time allocation procedures and, if necessary, offer advice to the observatory director or the STScI governing boards (STScI and AURA) of the observatory (to which the director reports) regarding possible improvements or attractive areas of "investment". Hence, fairness and scientific excellence can be reviewed by the community at several levels--the TAC, the Visiting Committee and the governing boards. Since the procedure envisaged by STScI and AURA (the governing corporation) follow this form, STScI's procedures should in principle win wide acceptance in the community.

Proper use of discretionary powers of the Director in assigning time is critical to the success of the enterprise. The most difficult "social" problems faced by the Director are those involved with time assignments outside those recommended by the TAC. It is important to ensure that in the face of enormous community pressure time is preserved for the following:

1) staff and instrument scientist time to ensure the proper operation and calibration of the science instruments and to develop innovative operating modes for the telescope and the instruments.

2) long-term proposals (carried out by both staff and general observers) designed not only to carry out observations of a synoptic character but also to attempt difficult, exploratory surveys or problems in which the questions posed may be profound but imprecisely articulated (by virtue of the challenging or fundamental character of the problem).

3) the programs for which ST was justified (e.g. to extend the distance scale to galaxies beyond the Virgo cluster) which will likely consume more time than either the instrument teams, the staff or any single general observer is likely to receive. Acceptable mechanisms to assign time for such "community" problems must be found.

4) innovative and imaginative programs of all types.

The current procedures admit solutions to all these challenges, but demand wisdom and statesmanship on the part of the STScI director and the support of the community. I offer no proposal to instill such characteristics in general but note the importance of exercising the existing time allocation procedures to ensure investments such as those outlined above.

With regard to criteria for judging STScI "successful" permit me to list several characteristics which I think will be appropriate barometers:

- STScI should engage the energies of the community in support of ST activities.
- STScI should be viewed as a focal point for community interaction with the ST for follow-on activities (e.g. scientific instrument upgrading and replacement, telescope modification, etc.)
- STScI should have a strong, active resident staff who are judged to be leaders in their research with ST; they should be respected by the community for their scientific competence and achievements. They should collaborate actively with members of the astronomical community at large and be regarded by the community as the primary source of expertise in using ST. In short STScI should be viewed by the community as a research organization of the first rank thereby ensuring the maximum scientific return from ST.
- STScI should be a strong independent organization, responsive to NASA, but strongly based in the astronomical community.
- STScI should be immune to pressures which measure success through false quantitive indicators such as throughput of observers, oversubscription ratios, numbers of proposals/investigators supported, etc. Instead, its success should be measured by the support it receives from scientists of the first rank as formally expressed by such community review bodies as the Visiting Committee.
- The observing program should be "balanced" in the sense that the best science in all areas of research should be scheduled. However, the institute should avoid a priori divisions of time according to discipline area. The system should be responsive to proposals offering at any given time, the best likelihood for gaining insight into the most challenging astrophysical issues.

Please let me know whether I can be of any further assistance to your committee.

Respectfully yours,

Stephen E. Strom

Stephen E. Strom
Astronomer, KPNO

SES/elf

cc: Dr. Radford Byerly

NATIONAL RADIO ASTRONOMY OBSERVATORY
EDGEMONT ROAD CHARLOTTESVILLE, VIRGINIA 22901
TELEPHONE 804 296 0211 TWX 510 587 5482

June 23, 1982

The Honorable Ronnie G. Flippo
U. S. House of Representatives
Suite 2321
Rayburn House Office Building
Washington, D. C. 20515

Dear Mr. Flippo:

Thank you for your letter of June 2 inviting me to submit a statement for the record of your recent hearings on the Space Telescope and the Space Telescope Science Institute. My statement is enclosed, and I am pleased to have this opportunity to submit it to you.

My term as President of the American Astronomical Society ended on June 7. The new president is Prof. A. D. Code, University of Wisconsin. Please be assured that the AAS is prepared to give you and your staff all possible assistance vis-a-vis the Space Telescope or other astronomy-related questions.

Sincerely yours,

D. S. Heeschen
Senior Scientist;
Past President, AAS

DSH/pj

cc: A. D. Code, President, AAS
P. B. Boyce, Executive Officer, AAS

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STATEMENT

by

D. S. Heeschen, Past President
American Astronomical Society

for

Subcommittee on Space Science and Applications
U. S. House of Representatives

June 23, 1982

The Space Telescope (ST) is eagerly awaited by astronomers everywhere. Its unprecedented power and capability will provide unique opportunities for astronomical research. We can safely anticipate that the ST will have a profound impact on our understanding of the Universe. We can expect the work done with it to enrich our culture as well as our science and to widen the horizons and stretch the imaginations of thoughtful people in all walks of life.

The Space Telescope Science Institute (STScI) will be responsible for scientific operations of the ST. Scientist-users of the ST will gain access to it through the STScI, and the observational data will be processed and disseminated by the STScI. The Institute provides the necessary interfaces between the telescope, the users, and NASA, and its role is therefore critical to successful utilization of the telescope. In this statement, I will make some random comments about how I feel the STScI might be operated and how its performance may be evaluated.

First, I note that the astronomical community already has considerable experience in operating several national research centers whose goals and problems are similar, but not identical, to those of the STScI. Thus the

Association of Universities for Research in Astronomy (AURA), which is responsible for STScI, also manages the Cerro Tololo International Observatory, Kitt Peak National Observatory, and Sacramento Peak Observatory. Similarly, Associated Universities, Inc. (AUI) operates the National Radio Astronomy Observatory. All of these National Observatories operate major astronomical telescopes for use by the larger community of scientists at universities and other institutions. Experience gained at these observatories should be--and is being--applied to the STScI.

I am very strongly in favor of vesting essentially all authority and responsibility for operation of the STScI in its director. He should be expected to run the Institute within broad policies and procedures set by AURA and NASA, without interference. His performance and that of the Institute should then be reviewed more or less continuously by informal or semi-formal means and periodically through formal review mechanisms. I believe this leads to better performance and greater accountability than can be achieved if responsibility and authority are diffused through committees or cumbersome approval procedures. I believe it also allows for quicker, more positive reaction by the parent organization, AURA, should a major problem arise.

For example, the director of STScI should be responsible for the allocation of observing time on the ST. He should set up mechanisms to accomplish this, which would be approved by AURA. Those mechanisms might include peer review, open or closed scheduling committee meetings, etc., but all such mechanisms should be advisory to the director and the director should be held accountable--to AURA and to the community of scientific users--for their appropriateness and success.

There already exist well-tested procedures for awarding observing time on major, federally funded telescopes where the available time is heavily oversubscribed and the competition fierce. They differ in detail from one telescope to another, but in all cases the director is ultimately responsible, and both the procedures and the results of their application are reviewed almost continuously by the users. The procedures have evolved with time and continue to evolve as situations and needs change. I think the same basic concepts can be carried over to the ST, modified to suit the particular requirements of that telescope.

This selection of programs to be carried out with the ST is one of the most important responsibilities of the director. The process needs to be fair and equitable and at the same time produce optimum utilization and productivity of the telescope. It needs to be understood by guest observers and by the community, and it needs to be reviewed regularly, but it need not be an open process. The results of the process will be available for all to see and will certainly be scrutinized continuously and in detail by the scientific community. As long as there is adequate communication between the ST, AURA, and the community, both informally and formally through visiting committees and users committees, this informal scrutiny is in fact the best review of the system.

Review of the STScI should be done at various levels. The first is the informal review by the "clients" of the Institute and by those who directly use the results of ST observations, such as I have just described for the selection process. In many ways this is the most important and effective review that will be done. The hundreds of scientists whose careers depend entirely or in part on the ST will be very effective critics, even though they are not organized and have no "official" voice. As a former director of a national astronomy center (I was director of the NRAO for sixteen years), I know that a director can operate effectively only if he has the concurrence and confidence of the community he and the institute are meant to serve. If something goes wrong, the managing organization, AURA, will hear about it quickly.

A second level of review should consist of periodic formal reviews by AURA and by NASA. These should primarily be reviews of past performance. A third level of review, by Congress, can be still less frequent. All of these reviews can be done through the usual mechanisms for formal review, by looking at the quality and quantity of scientific work that has been done, and at who did it.

During my sixteen years as director of the NRAO, we were subjected to a large number of formal reviews--by Congress, NSF, and our parent organization, AUI. I felt that most of these were reasonable and necessary. Their effectiveness depended much more on the specific people involved than on the particular nature of the review mechanism. But by far the most important elements in the operation and review of an institution such as STScI are that there be constant dialogue between the Institute and the scientific community and constant involvement of the community in the affairs of the Institute. It is the joint responsibility of AURA and of the Institute director to assure that these interactions are maintained.

Finally, I suggest that Congress may wish to consider the following role for itself in assuring that the STScI function properly.

1. Review periodically the function of the STScI and the policies established by AURA/NASA to fulfill that function.

2. Make sure that a sensible relationship exists between NASA and AURA. Don't let NASA over-manage the STScI and don't let the Institute be overwhelmed by bureaucracy.

3. Require that there be a strong director of the STScI, with adequate responsibility and authority. Make sure that sensible procedures exist for hiring the director. [This has already been accomplished--Giacconi is an excellent choice for director.]

4. Make sure that reasonable provision is made within STScI and NASA for performance reviews, and that the reviews are carried out.

5. Perhaps conduct an occasional Congressional oversight review of performance. Is the STScI adequately doing its job? I don't know how this might best be done, but I think some sort of broad, Congress mandated, review every five years or so might be appropriate. One possibility might be for Congress to ask NASA to appoint a high-level ad hoc review committee to report to NASA and to Congress. This was done by Congress and NSF halfway through construction of the Very Large Array, and I believe it was useful to all concerned parties. Such a review might work equally well for an operating organization as for a construction project.

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June 25, 1982

Mr. Ronnie G. Flippo, Chairman
Subcommittee on Space Science Applications
Committee on Science and Technology
U. S. House of Representatives
Suite 2321 Rayburn House Office Building
Washington, DC 20515

Dear Mr. Flippo:

Thank you for your thoughtful and perceptive letter about the Space Telescope. I was unable to answer until now because I was at the European Southern Observatory in Munich doing some research on quasars.

To be as concise as possible, the problem you outline is the crucial one for this expensive and powerful new telescope. In order to maximize the accomplishments will require a selection of projects and investigators which will open up new fields and produce new discoveries. The almost overpowering pressure will be to saturate the telescope with older, more obvious projects run by interconnected groups of influential astronomers.

The obvious projects will be done, of course, because there are a number of astronomers competing to do them. But to see that the innovative and ground-breaking projects are given an opportunity will be a truly difficult task. The best recommendations I can present at the moment are along the following lines:

(1) Time allocation committees should not have a majority of members from the large astronomical institutions. As large a percentage as possible of astronomers from smaller institutions should be on the decision-making bodies which approve Space Telescope projects.

(2) Any individual should be limited in the amount of time he receives. This is to prevent a large team of astronomers from forming and then simply rotating their names around on proposal after proposal and controlling a large block of time.

(3) An effort should be made to get one or two well known, innovative, and independent individuals on the allocation committee. It would be valuable to have some of these a little removed from specialized astronomy, perhaps even out-of-field individuals who can give some persepctive to the use of a radically new scientific tool.

(4) The review process should be open. That is, there should be no anonymous reviews of proposals. The general feeling as I sense it today, is that anonymous reviews invite irresponsibility and simply do not work.

I hope these comments are useful. Please feel free to call on me if I can be of further help to you.

I make the above statements as an individual astronomer and not in my role as an officer to the Astronomical Society of the Pacific.

Sincerely,

Halton Arp

Halton Arp
Astronomer
Mount Wilson and Las Campanas
Observatories

HA/ma

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Laboratory for Astrophysics and Space Research

June 10, 1982

Honorable Ronnie G. Flippo
Chairman
Subcommittee on Space Science and
Applications
U.S. House of Representatives
Rayburn House Office Bldg., Suite 2321
Washington, D.C. 20515

Dear Mr. Flippo,

I am in receipt of your letter of 2 June regarding your request for our help in answering a number of questions regarding the scientific utilization of the Space Telescope, including the question of the telescope observer selection process. The scientific community shares your enthusiasm for the Space Telescope and for the forthcoming development of the Space Telescope Science Institute. It is off to an auspicious beginning with Riccardo Giacconi as Director.

The questions you have raised are indeed important ones and, in the short time in which you have requested the report to be prepared for you, I have requested Prof. Lewis Hobbs (Director of the Yerkes Observatory of the Univ. of Chicago) to bring together the thinking of a small but important group of astronomers on the questions you have raised. This will be written during the next week and after some review by myself and others, will be forwarded to you hopefully by approximately June 18, 1982, as you have requested.

Let me take this occasion to thank you and your committee members for the vigorous manner in which you have expressed your support for space science and the execution of space science within the universities. Without the help of Congress we fear that the nation's leadership in space science will rapidly erode away. We are heartened by the interest which you and your colleagues have in this matter.

Sincerely,

J.A. Simpson
J.A. Simpson ym
Arthur H. Compton Distinguished
Service Professor of Physics

JAS/ym

SPACE SCIENCE WORKING GROUP

June 21, 1982

Honorable Ronnie G. Flippo
Chairman
Subcommittee on Space Science
and Applications
U.S. House of Representatives
Rayburn House Office Building 2321
Washington, D.C. 20515

Dear Mr. Flippo:

The enclosed statement was prepared in response to your letter of 2 June 1982. You requested our views on both the process by which observing time on the Space Telescope may be allocated effectively, and a statement on criteria which the Committee--in its oversight capacity--could use to judge the effectiveness of the Space Telescope Institute.

Your request for a prompt response did not permit the Space Science Working Group as a whole to consider this request and formulate a fully-coordinated response on behalf of the group.

Nevertheless, we were fortunate in being able to call upon leading astronomers who have been working on these policy questions for many years. At my request, and with the assistance of Professor L. Hobbs (Director of Yerkes Observatory), Professor Lyman Spitzer of Princeton University prepared the enclosed statement, which has been favorably reviewed by several astronomers concerned with these issues.

I hope that the enclosed document will be helpful to you and your Committee.

Sincerely,

John Simpson

J. A. Simpson
Chairman, Space Science Working Group

JAS/jpk
Enclosure

cc: R. Byerly, Jr.

c/o Association of American Universities • Suite 730 • One Dupont Circle •
Washington, D.C. • 202/466-5030

Effectiveness of ST ScI Operations

The letter of June 2 from Representative Flippo, Chairman of the House Subcommittee on Space Science and Applications, Committee on Science and Technology, raises basic questions on how the Space Telescope Science Institute (ST ScI) should be operated and how its effectiveness can best be evaluated. The primary focus of his letter is on the method of allocating telescope time to different observers, each with a different scientific program in mind. The present statement, prepared in response to Representative Flippo's letter, discusses the time allocation process which is now planned, some criteria for the effectiveness of this process, and how these criteria might be applied in a general oversight of the Space Telescope Science Institute and its functions after the Space Telescope has begun to obtain astronomical results.

Plans for allocating telescope time have been prepared by the ST ScI, drawing on the experience of AURA in allocating scarce time on its telescopes at Kitt Peak, Arizona, and Cerro Tololo, Chile; only about a third of the proposals submitted to these two observatories are actually awarded observing time. The comparable experience of the National Radio Astronomy Observatory and similar national scientific facilities has also been considered. According to these ST ScI plans, described in Report SO-07, "Science Operations Concept", April 6, 1982, proposals will be widely solicited from prospective General Observers in all countries, and will be evaluated in detail by a Time Allocation Committee, a broadly based group of some 10 scientists, whose members will serve staggered terms so that the TAC membership will change with time. This Committee will have available for each proposal detailed comments from several referees. Thus peer review will form an essential part in the selection of General Observers, and each proposal will be judged primarily on the basis of its scientific merit.

The extent to which the detailed reasons for TAC recommendations will be forwarded to applicants has not yet been established. Certainly some information must be provided, and equally certainly some details of the discussion must be withheld. For example, in the NIH review process, to which Representative Flippo refers, many "study sections" arrive at final ratings of grant proposals by secret ballot, and only the average rating obtained is forwarded to grant applicants, together with detailed written comments by outside referees and committee members, without any identification of the authors, though the membership of the reviewing group is, of course, well known. A more detailed description of the ST ScI Time Allocation Committee and its procedures is forwarded herewith as Appendix A.

As pointed out in this Appendix, the Director, ST ScI, is the final authority for allocating observing time on ST. He will be advised by his Time Allocation Committee. The detailed policies to be followed in these allocation procedures will be established by the Director, consistent with guidelines which are established by NASA and which will be discussed by a number of groups, including AURA's Space Telescope Institute Council and its Visiting Committee and also the Users' Committee. The procedures followed in allocating ST observing time are likely to change as a result both of these discussions and of experience gained in operation.

In view of the close and multiple interactions envisaged between ST ScI and these various groups, which will include many astronomers both from this country and abroad, it seems very unlikely that the procedures adopted for allocating ST observing time to General Observers will be perceived by many astronomers as unfair or unwise.

Some telescope time will be allocated outside of the peer review system. In accordance with the original NASA Announcement of Opportunity OSS-1-77, which requested proposals for development and construction of the ST instruments, the scientists chosen to provide these instruments have been guaranteed about a fourth of the ST observing time during the first 2 1/2 years; most of this guaranteed time is during the first year. The TAC will not evaluate plans for use of this guaranteed time. In addition, as indicated in Appendix A, it is planned that up to 15 percent of the available observing time (remaining after assignment of guaranteed time) will be allocated by the Director, ST ScI, to proposals not considered or not highly rated by the TAC. One purpose of this provision is to encourage the support of occasional new ideas which many astronomers may oppose because, as you state, these novel ideas do not fit current theoretical paradigms.

Concerning the more general question as to how ST ScI operations can be evaluated, once ST is in orbit, the following two criteria may be stated:

(a) The scientific output, measured in the overall advance of our knowledge of the Universe, should be maximized.

(b) The astronomical community as a whole should be drawn into the ST observational program as widely as possible.

While these two criteria may not always be consistent with each other when applied to individual programs, in the long run they should both support the welfare of astronomy as a tool in understanding man's relationship to the Universe about us.

To evaluate the effectiveness of the Institute, as measured by these two criteria, will require discussions with astronomers in many fields. The quality of the science, as compared with what might have been achieved with other policies, can be judged from discussions with a few of the most capable and broad-gauge scientists involved. The extent to which the ST observational program has involved a suitably broad group of astronomers, representing widely different interests and backgrounds, can be judged partly from statistics of telescope usage, and partly from comments provided by different groups of astronomers. However, it must be kept in mind that it will be quite impossible to satisfy every one, and that a distribution of observing time without a clearly primary regard to scientific merit or ability, would be a gross waste of a unique, powerful and expensive scientific resource. Experience with other national facilities indicates that a middle course can be found which will permit the full scientific exploitation of ST and will be supported by a broadly representative range of astronomers.

APPENDIX A

Extract from SO-07, Science Operations Concept
ST ScI Report 82012 A
April 6, 1982

Submitted to NASA for Approval

3.4 PROPOSAL SELECTION

The proposal selection will be accomplished by recommendation of the Telescope Allocation Committee (TAC), and approval of the Director. The TAC will review the proposals and referees' reports and recommend the observing time and priority to be allocated to selected programs. The GOSB[1] and OPD[2] will support this activity with estimates of the time required to carry out the program recommended by the TAC. The Director will have the final responsibility for approving the GO selection, the observing time allocation and priority level, and the overall observing program.

The Telescope Allocation Committee, which will consist of about 8 to 12 scientists selected to be broadly respresentative of astronomical subdisciplines and institutional affiliations, will meet and review the technical feasibility and referees' reports and subsequently advise the ST ScI Director on the relative merits of the proposals. The TAC will be chaired by a senior ST ScI scientist appointed by the Director and will include a NASA and ESA observer. The TAC will have about 1 week to discuss the proposals and to prepare its ranking list. The Committee will also make recommendations concerning the amount of time to be allocated to each proposal. In considering the total amount of time available, the TAC must allow for Director's Discretionary time, for commitments to IDTs* and ESA, for long-range programs, and for time necessary for spacecraft and instrument maintenance and calibration.

[1] General Observer Support Branch

[2] Operations and Data Management Department

In recommending any changes in the amounts of time requested, the Allocation Committee may consider many factors such as: the merit of the proposals that might be included if the amounts of time allotted to higher ranked proposals were reduced somewhat; how increasing or decreasing the amounts of time requested would affect the potential for achieving the scientific objectives of each of the higher ranked proposals, and how the scientific balance of the ST science program during the semester under consideration would be affected by these options.

The committee will make judgments on the priority with which the observations should be scheduled and executed. About 20% of the available time will be placed in the high priority category. The Operations and Data Management Department (OPD) will make every effort to successfully schedule and execute high priority observations during the semester for which they are proposed. If operational problems arise during the observations, efforts will be made to reschedule these observations during the same semester, even if they displace other observations (of lower priority).

Approximately 65% of the available time will be assigned to observations of medium priority. The OPD will make the best effort it can to get all these observations executed in the semester for which they were proposed, but operational realities may prevent a few of them from being accomplished. Medium priority observations that are not carried out will be carried forward to the next semester in which it is possible to do them so long as the total time being carried forward does not exceed certain guidelines. The committee will also recommend supplemental observations whose time totals between 20% and 50% of the available time. These will be used by the OPD to fill in the schedule when high and medium priority targets are not available. The sum of high and medium priority time is 85%, leaving 15% for Director's Discretionary time. If the Director does not assign the full 15%, then targets from the supplemental pool will be observed. Supplemental and medium priority targets will not necessarily be carried forward more than one semester; reproposal is expected. The amount of time allocated to high priority, medium priority, and supplemental observations will be adjusted based on actual experience. The goal will be to minimize the proposers uncertainties, while allowing for the oversubscription of observations which is operationally required.

Many of the proposals will be of a survey nature, i.e. similar observations of many members of a particular type of astronomical object. The intent of these programs will usually be to look for statistical correlations between measurable parameters so that general conclusions may be reached about the class as a whole. For proposals of this type, the TAC may recommend that a fraction of the observations be assigned a particular priority. After that fraction of the observations has actually been carried out, the priority for the remaining observations of the proposal may be reduced. This mechanism reflects the fact that the last observations of a large survey are usually of relatively low statistical weight so may be of less scientific importance than a single observation whose priority is the same as that of an entire survey.

The TAC will also make recommendations to the Director on variances from the standard data rights policy for proposals, such as long-term surveys, that clearly require special data rights considerations.

The TAC recommendations are expected to be consistent with policy contained in the NASA/ESA MOU (Memorandum of Understanding) (i.e. that, on the average, at least 15% of ST observing time be allocated to astronomers from the 11-nation ESA community) and with NASA policy for IDT (Instrument Definition Team) time. If substantial deviations occur over sustained periods the problem will have to be understood in detail, discussed with the STIC (Space Telescope Institute Council), NASA, and ESA as appropriate, and corrective actions taken.

It is important to recognize that all of this process is advisory to the Director of ST ScI, who has the final responsibility for selecting GOs and allocating time for their projects. The recommendations of the TAC, including the supplemental list, should be available to the Director about 15 weeks before the beginning of the observing period in question.

After the final decisions have been made, all proposers will be informed in a timely manner as to whether they were selected or rejected for this cycle. The Director (or a designee) might wish to communicate referees' comments and suggestions to the proposers.

Proposers included in the supplemental list should also be so informed, according to ST ScI policies. Rejected proposers will have the right to appeal to the Director. Within 30 days after completion of the allocation process, a report of the disposition of all proposals will be prepared by ST ScI.